THE EYE.

THE

STRUCTURE AND FUNCTIONS

OF

THE EYE,

ILLUSTRATIVE OF

THE POWER, WISDOM, AND GOODNESS OF GOD.

BY

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"The light of the body is the eye."

"Nature, therefore, is nothing else but God's instrument."

Richard Hooker.

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INTRODUCTION.

It is impossible to imagine an intelligent man engaging in the investigation and study of any portion of creation's wide domain, prosecuting the survey even of a single division of the grand Cosmos, without his becoming deeply interested in the world of use and of beauty thus opened to his intellectual view—without his feeling that the pursuit had, like the hoof of the winged horse, opened in the higher places of his intellectual being a fount whose streams yielded deep draughts of the true and the beautiful, a never-failing source of pleasurable happiness independent of external circumstances, and unsullied by the turbid waters of worldly striving. Before him lies an inexhaustible field, and never, like the great conqueror, need he weep because he has nothing more to overcome. Health and length of days, power of intellect, and industry unwearied, can but place him on the border-land of the vast realms of

knowledge, which stretch, boundless, away into the ages of eternity. "The man who studies forms of Nature has before him, so far as these forms are concerned, models of perfection—he has before him truth. His sole business is to analyse all the parts and all the bearings of that truth, and make them known to the world. The models and materials of his study are divine, and how much more they exceed those of any human artist will be manifested by a blade of grass, compared with which the most exquisite carvings in stone and ivory sink into insignificance."*

It is a question whether any object in creation presents, in equally small space, so much structural beauty and exquisite adaptation, as the Eye, either of man or animal, or affords so much illustrative proof of having for its Author a being of infinite love, wisdom, and power. Elevated, equally with the ear, above the other senses, by virtue of its mental and psychological fulfilments, the eye certainly offers more calculated to arrest the attention and excite the admiration of inquirers generally, whilst the readiness with which much of its organization may be seen, even in active, living operation, renders the whole subject more comprehensible to those who are unaccustomed to the consideration of

* Swainson.

animal structures. The author has endeavoured, without passing too lightly over the subject, to render it, both by description and illustration, as generally intelligible as possible. At the same time, there inevitably is much which cannot be comprehended or appreciated without some amount of thought and trouble; but the object is worthy of the means, however feeble or inadequate the pencil or pen of expositors* may be to do it justice.

The Chapter on Light has been confined within limits as narrow as are consistent with the consideration of the laws necessarily involved in the physiology of visual phenomena, and the anatomical detail has been principally directed to the elucidation of those points of structure most interestingly and directly connected with the function of vision itself; whilst throughout it has been the one endeavour to connect, in the mind of the reader, the perfections of the instrument with the attributes of its Maker, His power, His wisdom, His love, in nothing more visible than in the animal happiness, the intellectual and spiritual enjoyment which He has bounteously linked with the exercise of the organ of vision in all his creatures, from the creeping things of the earth, up to man, formed after his own image and likeness.

* In the "List of Illustrations" will be found the names of authors from whose works the figures are derived.

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Sensation.

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THE EYE.

CHAPTER I.

THE SENSES, AND SENSATION GENERALLY.

The word sensation, like other similar words which express ideas of an abstract rather than of a tangible nature, has been, and is often now, used in two different senses: the first, to express the communication conveyed to the brain or sensorium by the sense acted on; the second, the impression communicated to the conscious mind of the individual by the brain. How the impression received by the physical organ is taken up by the mental power we know not; to us it is an ultimate fact, beyond our finite powers of comprehension. All we know is the actual connection of the mental phenomena with that perfect and wonderful

system of nervous telegraph by which the spiritual of man, the mental of the animal, holds communion with the natural and material.

Knowing, then, that the action upon the sensorium, and the consciousness excited thereby, are inseparably connected; moreover, that the word sensation is used to express both actions separately—a separation, nevertheless, of which we cannot form an idea in our own minds—it is thought better, in using the word in this treatise, to keep that inseparability in view, and to regard the impression exerted upon the sensorium, or material part, as necessarily exerted upon the mind, or immaterial part, at the same time, and thus to include both actions in the same expression. At the same time, there is in this no ground for interference with the metaphysical idea—no countenance for the illogical absurdity, which would make mental phenomena merely the result of physical organisation.

In accordance with the above, the definition is adopted, that sensation consists in the reception by the sensorium (and mind), through the medium of the nerves, of certain definite impressions, these impressions being the result of changes in the nerves themselves—depen-

dent for their effect upon the sensorium—upon the peculiar energy or quality of the individual nerve, which is capable only of being affected by, and of conveying, one certain species of impression, and no other. Thus, it being the peculiar energy or quality of the optic nerve to convey the sensation of light or colour, it is precluded, by virtue of this endowment, from conveying any other description of sensation. "The essential nature of these conditions of the nerves, by virtue of which they see light and hear sound*—the essential nature of sound as a property of the auditory nerve, and of light as a property of the optic nerve, of taste, of smell, and of feeling—remains, like the ultimate causes of natural phenomena generally, a problem incapable of solution."

Although every man is conscious of being in his own person susceptible of the action of the senses, it can only be matter of inference that other sentient beings are capable of the same impressions—undoubtedly of certain inference as regards our fellow-men, and of

* "When we say sensation and thought are functions of the nervous system, we mean only that this system furnishes the conditions under which sensation and thought in the living body take place."—*Alison's Physiology*, p. 121.

most probable inference as regards the higher animals. As we descend in the scale of creation, however, and find either an extremely low development of the nervous system, or no perceptible development at all, we have no data by which to measure the probable amount of sensibility to impressions, either external or internal, "although there is good reason to believe that all beings of a truly animal nature possess a consciousness of their own existence." It is evident, however, that this simple consciousness of existence, which we judge to be possessed by even the lowest tribes of animals, is very different from the arrangements of special sense enjoyed by the higher.

For the due exercise of the special senses—touch (a portion of general sensation), taste, smell, hearing, sight—two conditions appear to be more especially necessary: the integrity of the connection of their nerves with the central mass of the nervous system, and the free circulation of arterial blood throughout that system. Moreover, it is evident that the transmission of the special sensation to the sensorium, by the special nerve, is not simply as by a conductor, but is dependent upon certain changes peculiar to the nerve itself. This we

know to be the fact; the nerves are capable of conveying to the sensorium impressions similar to those excited by external influences, when no such influences have been exerted. Thus, individuals will frequently describe sensations as if experienced in the toes or fingers long after the amputation of the limb. The sensation of disagreeable odours may result from functional disorder of the olfactory nerves, or luminous appearances be apparently visible to an eye which had been extirpated. Further, the single stimulus of electricity, properly applied, is capable of exciting in each nerve its own peculiar energy. Applied to the eye, the sensorium receives the impression of light;* to the ear, of sound;† to the nostrils, of the odour of phosphorus; to the tongue, of acid; to the skin, of prickling. Not only, however, are the special sensations of the nerve liable to excitation by these external agencies, but also by internal means. Disorder of the bodily health, whether occurring spontaneously or as

* Humboldt.

† Volta states, that while his ears were included between the poles of a battery of forty pairs of plates, he heard a hissing and pulsating sound, which continued as long as the circle was closed.—*Müller's Physiology*, p. 1063.

the result of medicinal or other substances, more especially of narcotics, may have a similar effect.

It has been remarked that one nerve of special sensation cannot become substituted for another; the optic nerve cannot convey the impression of sound, nor the auditory that of light. This might have been expected, but we also find that these nerves have not the faculty of conveying common sensation. The optic nerve may be divided in operation without pain; the only sensation—if the function be not destroyed by disease—being that of a flash of light. In Magendie's experiments, the olfactory and optic nerves, and the retina, were found insusceptible of excitement by mechanical irritation.

In the higher tribes of animals, in which the five senses exist in what may be considered perfect condition, one of the five is frequently more or less modified or developed, according to the requirements of the creature, whether for the attainment of subsistence, the preservation from injury, or both, and an acuteness of perception possessed which is not experienced by man, at least

in a civilized condition. It is certainly true that, amid savage nations, the constant incentive to the keen exercise of the senses in procuring subsistence and guarding against danger, must and does call forth in them a power of discrimination they would not otherwise have; but it is a question whether this power ever equals in intensity the natural instinctive sense of the brute. The mere animal acuteness of perception, moreover, is very different from the educability of the senses bestowed upon man—the faculty of distinguishing the useful and the beautiful; in short, of surrounding himself with all that can add to the comfort and gratification of sense, of appropriating all that can elevate him as a social, moral, an intellectual and religious being.

CHAPTER II.

Light.

LIGHT—HYPOTHESIS OF NATURE—VELOCITY, ETC. — RELATION TO BODIES — LUMINOUS—OPAQUE — TRANSPARENT—COLOUR — REFRACTION—LAWS OF—PLANE SURFACES—CURVED SURFACES — DENSITY OF MEDIA — LENSES—FOCAL POINTS — FORMATION OF IMAGE—SPHERICAL ABERRATION — REFLECTION OF LIGHT—CHROMATIC OR COLOUR PHENOMENA—PRISM—RECAPITULATION.

CHAPTER II.

LIGHT.

"'Tis the sun that maketh all things shine."

WHAT is light? What is that which we are told "was," at the fiat of the Almighty, "the prime work of God," the first of distinctly created things, and which has, ever since that fiat went forth, ceased not its shining? We know that it is light by which, as our visual organs are constituted, we are enabled to take cognizance of the colour, size, shape, and position of things around us. We know that this light is subject to laws which it is in our power to trace; but what it is in itself, we know not certainly, however beautiful, and apparently adaptable, are the theories we frame respecting its real nature. This, however, we do know, that the great source of light is the sun—that bright and glorious luminary, which may be taken as a type of the Deity Himself: its life-reviving rays, the

beams of His divine Love and Wisdom—their warmth, the Good—their light, the True.

In order that we may properly understand and fully appreciate, the exquisite structure, and varied adaptation, by which the Creator has fitted the organs of sight to the habits and requirements both of man and of the lower animals, it is requisite that the properties and laws of light—at least so far as they affect vision—should be rightly comprehended. With the consideration of these it is proposed to occupy the present chapter.

The actual nature of light, like sensation, must be classed amid those ultimate facts which encompass the domain of human knowledge, which seem to say to the highest human intellect, "Thus far shalt thou come, and no further." Fortunately, however, this necessity, which compels us, in the absence of certain knowledge, to search out and frame the theory apparently best adapted to explain the phenomena and laws of this wonderful agent of God's purposes, does not interfere with or hinder the investigation.

Two theories of the nature of light have been principally entertained in modern times. The first, that of Newton, which supposed light

to consist of material emanations or atoms, continually thrown off, with immense velocity, from the sun or other self-luminous body. The other, modified by various observers, and now most universally adopted, usually called the "Undulatory Theory," supposes light to consist in, or to be the result of, rapid oscillations of the supposed spherical atoms, of the imponderable, elastic, ethereal fluid, which is conjectured to fill up the interspaces of the atoms of all material things, including the air itself, and to be extended, not only beyond the narrow limits of our aerial atmosphere, but throughout universal space. Thus it is thought that the sun, or even a simple candle, by first exciting this oscillation in the particles next to itself, occasions it to pass, or to be communicated, with immense rapidity from one particle to another, until at last reaching the eye, it occasions the sensation of light by its action on the nerve or retina of that organ. By this theory, light results from the excitement caused by oscillation or undulation, darkness from its absence. It is calculated, however, that a certain rapidity of oscillation must be generated before the sensation of light can be excited in the eye.

Whatever the nature of light, it is found to pass through air at the immense velocity of 192,000 miles per second; from whatever agent it may be projected, its waves or undulations, like those of sound, being transmitted in every direction from the luminous body with an intensity inversely as the square of the distance. It may here be well to caution the reader against confounding what are called the "rays" of light with the light itself, the former being only imaginary straight lines, whether in language or diagram, taken to indicate the direction of the effect of the agent.

All bodies may be regarded, in relation to light, as falling under the head of luminous, opaque, transparent. According as light comes in contact with one or other of those classes of bodies, its agency is modified. Thus if a ray, proceeding from one luminous body, meet with a ray from another, the intensity of each is interfered with. Some bodies may check its undulations altogether, others, by having fresh undulations excited in the ethereal particles occupying their interspaces, project rays from themselves which convey to the eye a correct idea of their colour and form. Some may reflect or refract the rays of light without

altering their character, whilst others have the property of dividing light, as it were, either giving rise to the double ray of polarization, or to the prismatic colours of the spectrum.

It has already been remarked that black is merely the absence of all light or colour, consequent upon the power possessed by all bodies presenting a black appearance of checking luminous oscillation. Colour, on the other hand, is thought to be the result of differences in the rapidity of the oscillatory movements excited by various bodies, and not of any actual property of colour in the bodies themselves, each colour requiring its distinct scale of undulations; for instance, in order that the sensation of the colour red may be conveyed to the eye, it is computed that four hundred and seventy-seven millions of millions of oscillations in a second must be communicated to the particles of ether—an amount of velocity and action totally out of the power of our minds to comprehend.

REFRACTION OF LIGHT.

Rays of light may be divergent, convergent, parallel, relatively, to each other; each ray,

however, maintains its original, individual, straight direction, so long as the transparent medium through which it passes continues of uniform density. Should, however, the ray of light pass from a rarer into a denser medium, as from air into glass or water, and be incident in any other direction than the perpendicular, the straight line of its original course is changed—it becomes refracted, or, as it were, broken; if it fall perpendicularly upon the surface of the medium, the direction remains unaltered. The simple but illustrative experiment on this refraction, of the oblique ray passing from a rarer into a denser medium, is familiar to all. A coin placed in the bottom of a cup, so that it cannot be seen by a spectator standing at a certain distance, instantly becomes visible on filling the vessel with water, in consequence of the refraction, or bending, as it were, of the rays, which formerly passed in straight lines. The person may be said to see round a corner. Again, if A B (Diag. I.) be a plate of glass with parallel sides, a ray of light, P, falling upon it perpendicularly from the point L, will pass through its straight course unaltered; on the other hand, the oblique rays, O O, instead of continuing each

its original straight course to F, will be refracted towards the perpendicular, as soon as it enters the denser medium; on leaving it, how-

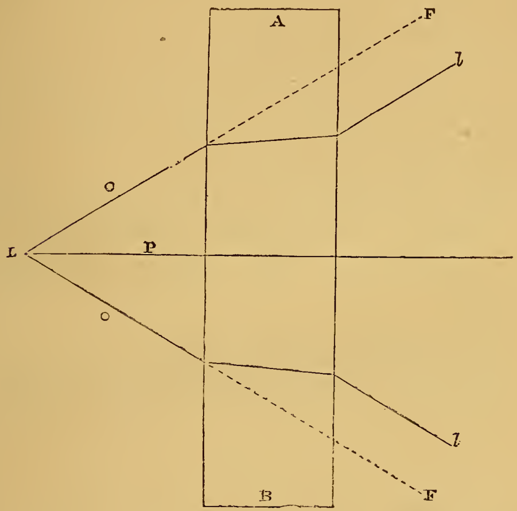


DIAGRAM I.—REFRACTION OF RAYS OF LIGHT TRAVERSING A DIOPTRIC MEDIUM BOUNDED BY PLANE SURFACES.

Diverging Rays.—L, Common Point. A B, Plate of Glass. P, Perpendicular Ray not refracted. O O, Oblique Rays refracted towards the perpendicular to the point at which they enter A B, away from the perpendicular to the point at which they leave A B.

ever, and again passing into the rarer medium, another refraction takes place, now from the perpendicular, the rays assuming a direction

exactly parallel to their original one, and passing on to *l l*. It is evident that the refracting medium, A B, without altering the relative directions of the rays, has yet exercised considerable influence over the amount of their divergence in a given space.

No two laws of optics have a more important bearing upon the physiology of vision than those just illustrated, viz. :—

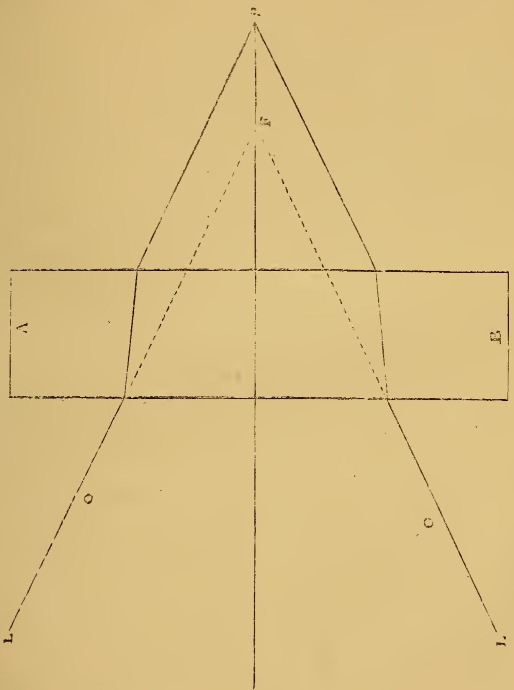
I. Light passing from a rarer into a denser medium, is refracted *towards* the perpendicular of the surface on which it falls.

II. Light passing from a denser into a rarer medium, is refracted *from* the perpendicular.

Reversing the diagram, it is evident that a similar refracting agency acting upon the rays O O (Diag. II.), must, in like manner, alter their original direction, and cause them, instead of meeting at F, to delay their point of junction as far as P.

There is considerable difference in the refracting power of various transparent, or, as they are called in optical science, "dioptric" media: generally, the greater the density, the

DIAGRAM II.—REFRACTION OF RAYS OF LIGHT TRAVERSING A DIOPTRIC MEDIUM BOUNDED BY PLANE SURFACES



Converging Rays.—Refractions similar to Diagram I. Effect reversed.

greater the power of refraction. To this law, however, there is an exception in the case of inflammable bodies, which are, comparatively, more highly refractive than any other; a circumstance which first led Sir Isaac Newton to hazard the assumption that the diamond, from its extreme power of refracting light, was inflammable. The truth of the assumption was afterwards fully proved, when the diamond was found to consist of pure carbon. Moreover, the refracting power of a transparent medium exerts considerable influence over the velocity of light transmitted through it. The greater the refraction, the less the velocity.

It is not all the rays impinging upon the surface of a dioptric medium which enter it; a certain number always undergo reflection, in proportion to the obliquity of their incidence, until at last this becomes so great, that, instead of being permitted to enter, they are reflected from the surface on which they impinge, at what is called the "limiting angle" between refraction and reflection.

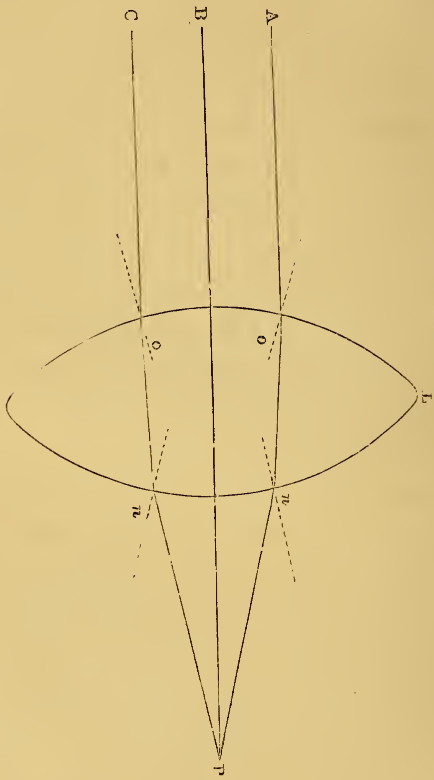
Hitherto, the action of light in connection with refracting media, bounded by plane surfaces only, has been considered, but the surfaces of the refracting media of the eye being

all of them curved, in order properly to understand the physiology of that organ, it becomes necessary to examine how the effects already pointed out are modified by the difference in form.

Refracting media with curved surfaces are called lenses, and may be of very different forms—spherical, double convex, plano convex, concave, meniscus, &c. As, however, the same law, differently applied, explains the action of the various kinds, it will be sufficient here to consider that of the commonest, and the one most nearly connected with the physiology of vision—the double convex lens.

Diagram III. represents the section of a double convex lens through its centre, but of course the convex sides may have any degree of curvature, from nearly spherical to almost flat; or, as in the lens of the eye, may be unequally curved. A B C are supposed to be three parallel rays of light incidental upon one of the convex sides of the lens, L; B, falling perpendicularly, will of course pass through the centre unaltered in direction; A and C, however, being in the position of oblique rays as regards the surface of the lens, will be refracted towards *o*, the perpendicular to the

Diagram III.—Refraction of Rays of Light traversing a Dioptric Medium bounded by Curved Surfaces.



Parallel Rays.—L, double convex lens. B, central ray not refracted. A C, eccentric rays refracted towards perpendicular. *o*, of point of incidence, away from perpendicular. *n*, of point of exit. P, focus of parallel rays.

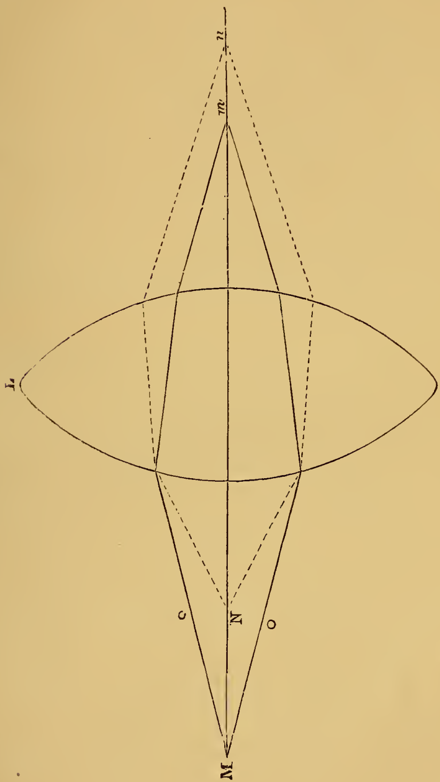
plane of the point at which they meet the curve; this refraction throws them into convergence, and this convergence is rendered still greater, when, on leaving the lens, and passing into the rarer medium of the atmosphere, each ray is refracted away from *n*, the perpendicular, to the plane at which they part from the curve. The evident effect of this double refraction and double convergence is to cause the originally parallel rays, A and C, to intersect. If these two rays have been equidistant from the axis ray of the lens, B, they will intersect it, and each other, at the same focal point, P; continued beyond this they will become divergent. This focal point, P, is the principal or focus of parallel rays, and is of course dependent for its position upon the density of the substance forming the lens, and upon the amount of curvature of its surfaces. The denser the lens, and the more convex, the greater will be the amount of refraction, the more marked the convergence of the rays, and the nearer their intersection, or focal point, to the refracting medium. The same rule which applies to the parallel rays, A C, is applicable to all parallel rays equally distant from B; they will intersect at P. *Vice versa*, luminous rays

diverging from a point exactly in the focus of the lens will be rendered parallel by passing through it.

Diverging rays, passed through a double convex lens, are necessarily refracted to a point beyond, and not to be confounded with the principal focus of the lens. The further distant the luminous point yielding the rays, that is, the more nearly they approach parallelism, the nearer of course does their point of intersection lie to the principal focus; on the other hand, the nearer the luminous point to the lens, the more divergent the rays, the further from that focus will they meet. *Example.*—Two diverging rays of light, o o (Diag. IV.), emanating from a point, M, and passing through the lens, L, would be refracted to the point, *m*, beyond the principal focus, whilst rays still more divergent, proceeding from N, would intersect only at a point, *n*, still further from that focus.

By a little consideration, the foregoing observations, which have been made solely with reference to isolated rays, will explain the formation of an image, by lenses, as it is formed in the eye. An image of any body is but a collection of the various rays proceeding

DIAGRAM IV.—REFRACTION OF RAYS OF LIGHT TRAVERSING A DIOPTRIC MEDIUM BOUNDED BY CURVED SURFACES.

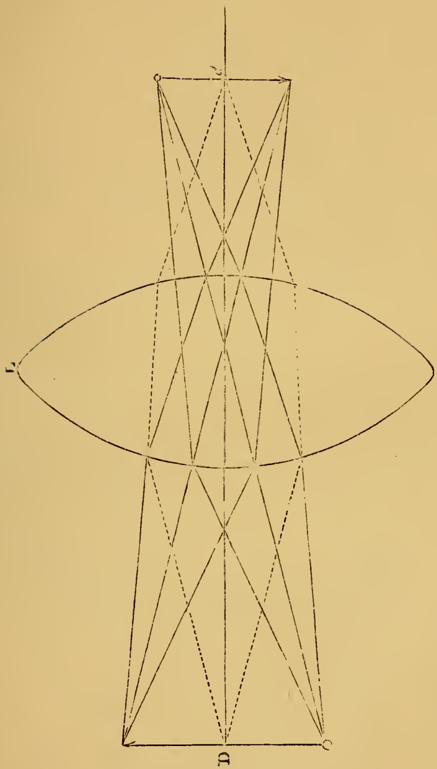


Diverging Rays.—L, double convex lens. M, distant point of divergence of o o, which are refracted by the lens, and converged to *m*. N, nearer point of convergence; the rays only converged at *n*.

from that body, and these, individually, are all subject to the same laws. L (Diag. V.) represents a double convex lens, through which are transmitted rays from the body, D, with the effect of forming an image of that body on any receptive surface, placed near the proper focus. If the direction of the rays represented in the diagram be examined, it will be seen how, in accordance with the laws of refraction, the image of the body, D, is necessarily represented inverted at *d*.

Rays which pass through the centre of a lens, even if they fall obliquely, do not emerge from it with much alteration in their direction, the two surfaces near the centre being so nearly parallel, as to approximate the effect of the refracting agent to that of the glass plate (Diag. I.). This is a point of some importance in connection with the physiology of vision. Moreover, the focus, or common point of convergence of all such central rays, will be tolerably well defined. As, however, the pencils of rays approach the circumference of the lens, that is, recede more and more from the central or axis ray, they necessarily become more and more oblique, relatively, to the curvature of the refracting surface; the consequence is, they

Diagarm V.

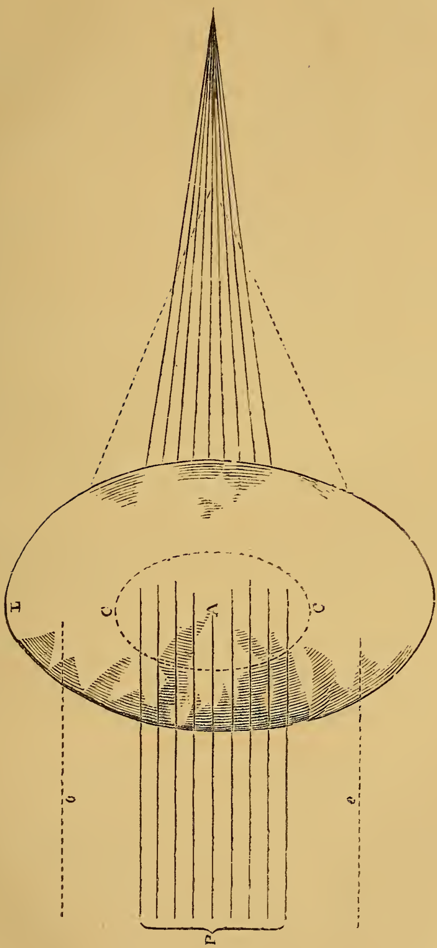


Formation of reversed image *d* of image D, by refraction of rays traversing double convex lens.

are more strongly refracted or converged than those which pass through or near the centre, and thus intersect at a point nearer to the lens than its principal focus, causing some degree of confusion in the definition of the image. This effect is known by the name of spherical aberration, and is inseparable from the refracting agency of lenses with spherically curved surfaces.

Let L (Diag. VI.) represent a fore-shortened view of the surface of a double convex lens, and A its central or axis ray. "The focus for each circle of rays from the axis to the margin of the lens is different, becoming nearer to the lens the more remote the rays are from the centre." All which fall within such a distance from it, as the imaginary circle C C includes, will converge so nearly to one point as to form a perfectly well defined image. On the other hand, rays such as *o o*, passing through the lens near its margin, will, as we have seen above, be converged more rapidly than the former, and tend to confuse what would otherwise be distinct. This "aberration from sphericity" is, indeed, capable of correction, by modification of the curvatures of the lens, or, as in the eye, by difference in

Diagram VI.



Foreshortened view of double convex lens, L, showing convergence of parallel rays from P, if traversing near the centre of lens. Spherical aberration of rays, *o o*, traversing margin.

the density of the central and marginal media. It is, however, more easily, and, for all practical purposes, sufficiently corrected by the interposition of an opaque ring, or, as it is called in optical science, a "diaphragm," between the luminous body and the marginal portion of the lens, so as to intercept all rays sufficiently eccentric to cause confusion by spherical aberration. It is evident that the interposition of such a ring around the margins of the lens (Diag. VI.) will have the effect of interceptin all rays, such as *o o*, the refraction of which would interfere with the principal or image of the central rays.

The diaphragm is much used in the construction of optical instruments, and in the eye we find it in the most perfect conceivable form.

REFLECTION OF LIGHT.

Hitherto, the effects of transparent, or, as they are called, dioptric media, upon light, have only been considered; it is with these we chiefly have to do in the physiology of vision. When rays of light, instead of falling upon a transparent body, impinge upon a plane

polished surface, or mirror, they are for the most part reflected, that is, thrown back into the medium through which they reached the mirror. This reflection takes place according

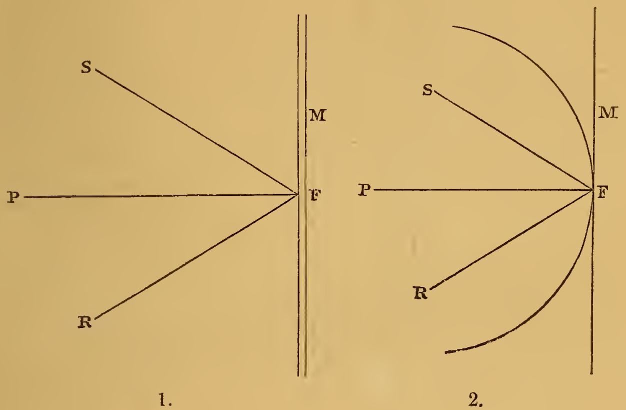
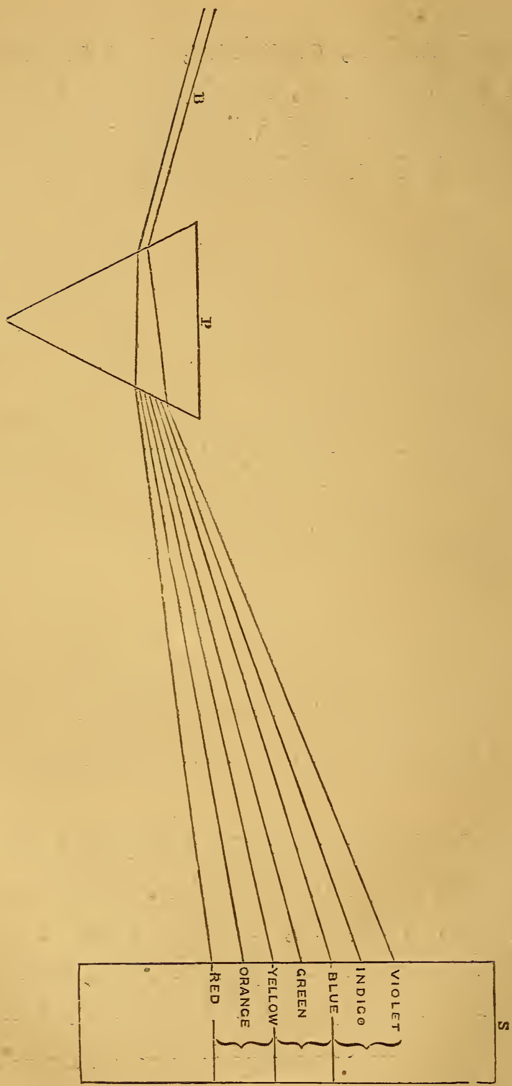


DIAGRAM VII.—REFLECTION OF LIGHT.

1. From plane surfaces. 2. From curved surfaces.

to the fixed law, that the angle of incidence equals the angle of reflection. Thus a ray, R (Diag. VII., 1), falling upon a plane polished surface at the point F, will, on undergoing reflection, pass off towards S, forming equal angles on each side of the supposed perpendicular, P.

DIAGRAM VIII.



Decomposition of light B, by prism P, and formation of prismatic spectrum, S.

Precisely the same law regulates the reflection of rays impinging upon the surface of a curved mirror. In this case, each point of such a mirror on which luminous rays fall is regarded and acts as a small reflecting plane in itself. A ray, R (Diag. VII., 2), falling upon the surface of a concave mirror, at the point F, the tangent, M, will represent the direction of the plane from which, in accordance with the above law, it must be reflected to S.

It is unnecessary, for the purposes of this treatise, to pursue further the consideration of the laws and phenomena connected with reflection of light.

PRISMATIC OR CHROMATIC PHENOMENA OF LIGHT.

According to the simple law, rays of light passing through a prism ought, whilst undergoing refraction, to remain at the same time parallel. This, however, is found not to be the case.

"If a beam of the sun's light, B (Diag. VIII.), fall obliquely upon the prism, P, it will be refracted twice, namely, by its anterior

and by its posterior surface; but, instead of the rays continuing parallel in their new course, the beam is spread out, and, when received upon an opaque surface, presents the colours of the rainbow."* The image thus formed by the unequal refraction is the prismatic spectrum S (Diag. VIII.), and is composed of seven colours, arranged in the following order: violet, indigo, blue, green, yellow, orange, red; violet being the highest, or most refrangible, the other rays range below it in the order given. The boundaries of the colours, however, are not distinct; they gradually melt into each other.

Sir Isaac Newton, who was the first to perform the experiment of separating light by the prism, inferred from it that white light is composed of seven primitive colours. It is now more generally thought that three colours only,—blue, yellow, red—are primitive, and that the others are compounded by the intermixture of these at their edges in the prismatic spectrum.

The fact elicited by the prismatic analysis, that white light is composed of the coloured rays, is susceptible also of synthetical illustra-

* Müller.

tion; the three kinds of coloured rays, by proper management or super-imposition, are capable of being combined to form white light.

The colours of natural objects are supposed to result from the absorption or transmission of such of the component rays of white light as do not appear. Thus a flower, it is said, appears blue, from the fact of the surface of its petals absorbing the red and yellow rays of the light shining upon them.

Although it is only by the prism that the separation of white light into its component coloured rays is perfectly brought out, any other transparent refracting medium, though not prismatic, exerts partially the same effect, causing what is called "chromatic aberration." The unequal refraction causes objects, seen through such refracting media, to appear surrounded by a fringe of prismatic colours. This long proved an obstacle to optical improvement, but was at last removed by the discovery that different transparent media—even different qualities of glass—exert different refractive effects upon the component coloured rays. Taking advantage of this, opticians, by a combination of lenses, formed of different

kinds of glass, one to neutralize or correct the chromatic aberration of another, succeed in producing "achromatic" optical instruments, free from the confusion of colour which formerly prevailed. In the human eye, it will be found that provision has been made for the same corrective purpose.

To recapitulate, we find light taking its origin from the sun, or other luminous body, passing in straight lines in all directions, unless interrupted.

INTERRUPTED, becoming absorbed by opaque bodies of one description, or reflected more or less by others, imparting to the sense of sight, the idea of black, of white, or of colour.

REFLECTED, under fixed laws.

TRANSMITTED by transparent media, undergoing refraction according to the density of the medium, and the relative positions of the luminous rays, and of the receptive surface; or the ray split, as it were, by polarization, or divided by the prism into the rainbow colours of the spectrum.

The consideration of the phenomena and laws of light has now been carried as far as requisite for the object of the present treatise—for the due understanding and proper appre-

ciation of the beautiful constructions and adaptations by which the Creator has fitted the different forms of visual organs, to act in unison with the light of the material universe—that "light from whose rays all beauty springs."

CHAPTER III.

Anatomy of Human Eye.

ORGAN OF VISION GENERALLY — ORBITS — EXTERNAL APPENDAGES—EYELIDS—ORBICULAR MUSCLE—CONJUNCTIVA—MEIBOMIAN GLANDS—LACHRYMAL CANALS—EYELASHES—LACHRYMAL GLAND.

CHAPTER III.

ANATOMY OF HUMAN EYE.—THE ORGAN OF VISION GENERALLY.

THAT vegetables are in a degree sensible to the action of light over their entire surface, there can be no question. It is also probable that some of the lower tribes of the animal kingdom, such as the polyps and others, possess no higher endowment than this kind of diffused sensibility to the agent; they do not, at least, present organ or formation to which a faculty resembling what we call sight, can be ascribed. The lowest and simplest appearances to which the name of eye can be given are the "eye-dots" of the medusa and of the star-fishes, or the "ocelli" of the annelida; and these organs, probably, do little more, if as much, than convey to the animal an impression of the more marked differences in form and colour, destitute, as they are, of optical apparatus for the forma-

tion of a distinct image upon the nervous expansion, which, surrounded by a little black pigment, and shielded by a cornea, constitutes, with in some cases the addition of a lens, their simple eye.

As the consideration of these simple eyes, as well as that of the second class of visual organs—the highly compound eyes of insects and crustaceous animals—will engage a future section, we pass at once to the third and highest class, that of which the human eye may be taken as a type; in which accurate and perfect vision results from the transmission of rays of light through refracting dioptric or transparent media, and the formation of exact images of external objects upon an extended sheet of nervous substance placed in a dark receptacle—the interior of the eye—much in the way that images are thrown upon the white surface in the camera obscura.

The eyes of the higher mammalia, and of vertebrated animals generally, very nearly—in essentials at least—resemble those of man; and though, throughout the various tribes and species, we find modifications of the visual organs, suited to the habits aud requirements of the creature, and properties possessed which

do not appertain to human sight, these are the result rather of appendages to the optic apparatus than of any greater perfection of the apparatus itself; and may well be entered into, after the consideration of that beautiful construction and wonderful adaptation by which the Creator has fitted the human eye for its offices and powers: then shall we have seen how each and all of these contribute to the one great end of perfect vision, and how all are constituted in perfect harmony with the laws which are impressed upon and regulate the rest of material creation. A thorough understanding of the structural beauty and optical perfections of the human eye will better prepare us to appreciate the superadditions; but whether it be the focal eye of the mammal or bird, the facetted organ of the butterfly, or the simple ocellus of the leech, we shall find each and all telling of Him who created them, and testifying, in language eloquent though soundless, "the hand that made us is divine."

THE HUMAN EYE—THE ORBITS OR EYE-SOCKETS.

The orbits or sockets of the human eyes are two quadrilateral, hollow pyramids (Fig. I.), situated at the upper part of the face, and are formed by the union of portions of seven different bones; they are pierced by nine foramina or holes, eight of which give passage to blood-vessels and nerves, the ninth to the duct (Fig. IV., B 4), by which the lachrymal fluid is conducted into the nose.

In these bony cones, along with its muscles, nerves, blood-vessels, and other appendages, and suspended by a fascia of its own, is placed the eye-ball or globe, every space otherwise unoccupied being well filled up and cushioned with fat, and all care taken for the perfect inward security, but at the same time perfect mobility, of the important tenant. Violence from without is provided against by the strong bulwark-like projection formed by the margin of the orbit itself. To ward off lesser external irritations which might prove obnoxious, there exists that beautiful combination of protecting agents, the "tuta-

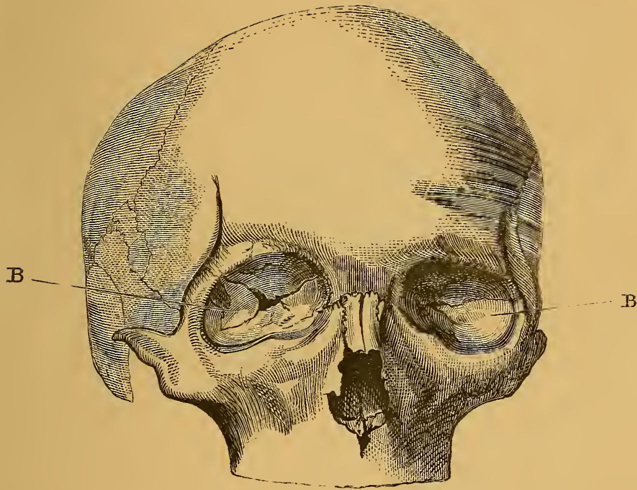


FIGURE I.—VIEW OF ORBITS OR EYE-SOCKETS, SHOWING THEIR QUADRILATERAL CONICAL FORM.

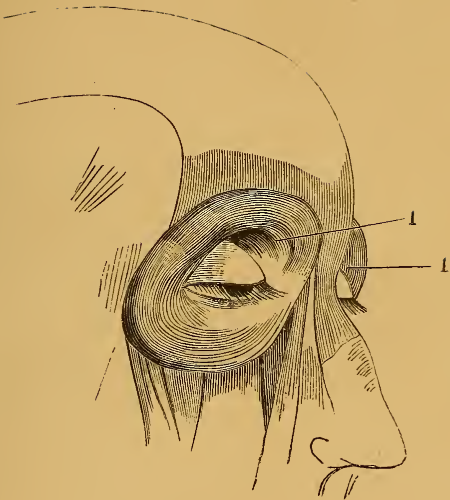


FIGURE II.—1, ORBICULAR MUSCLE OF THE EYE-LID.

mina"* of the eye. The pent-house of the eye-brow above shields from excess of light, or from trickling perspiration; the fringed curtains of the lids are ever ready to close over, and instinctively to protect their charge; and the ever-flowing stream from the lachrymal gland ceases not to cleanse the surface of the ball from all that might mar or irritate.

The sockets of the eyes do not, as many might suppose, look straight forward, but outward; that is, lines drawn through the axis of each must diverge from a common point posterior to the apex of the cones. The optic or sight nerves of the eye, each of which pierces the corresponding socket at the apex, exactly follow this course (Fig. III.), diverging from their commissure or point of junction within the skull. On the other hand, as a glance at the same Diagram will show, the axis line of each eye (Fig. III., 3) is parallel to that of its fellow, but intersects that of its own orbit. The consequence of this arrangement is, that each optic nerve enters the eye-ball rather at one side. Its importance we shall see hereafter.

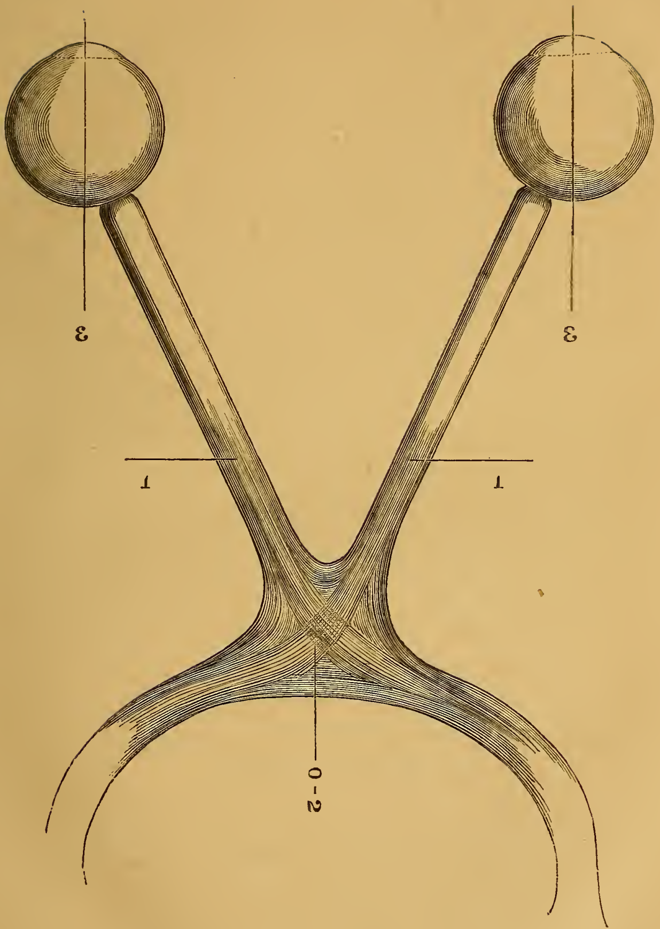
* Protectors.

EXTERNAL APPENDAGES—EYE-LIDS.

The general appearance and connections of the eye-lids in man are sufficiently well known, and any one who will be at the trouble of examining his own for a minute or two before a mirror, may easily verify many of the less apparent particulars here mentioned. The external skin of these protective curtains, loose in itself to permit of free motion, derives its support and general form from a thin sheet of elastic but firm cartilage, which lies beneath it in each lid (Fig. IV., B 1, 2). This cartilage may easily be felt by gently pinching the lid. In the upper it is considerably wider than in the lower, and in both its curvature is exactly adapted to that of the globe.

The angles of the eye form, as it were, pivots for the movements of the lids. These are connected and strengthened, at the inner angle, by a strong horizontal tendon, which also affords attachment to the fibres of the orbicular muscle (Fig. II., 1). This muscle, the office of which is to close the eye-lids, surrounds the margin of the orbit. Some of its fibres are situated between the skin and cartilage, more

Figure III.—Optic Nerves and Eye-balls.



1, 1, Optic Nerves. 2, The Commissure of the Optic Nerves. 3, Line of Axis of Eyes.

particularly of the upper lid, which, in consequence of its greater curvature, is principally concerned and acted upon in closure of the eyes. As all are aware, the act of closing the eyes, or of winking, is involuntary. If violence is offered, the movement is sudden, almost spasmodic; but generally it does not exceed a gentle sweep of the lid, by which the ball is continually kept clear from all impurity, the lachrymal fluid diffused over its surface, and at the same time assisted in its passage through the ducts by the gentle pressure exerted. Should, as sometimes occurs, this act be interrupted, its importance is speedily attested by the painfully inflamed state of the covering membrane of the eye-ball, which supervenes.

CONJUNCTIVAL OR COVERING MEMBRANE OF LIDS AND GLOBE.

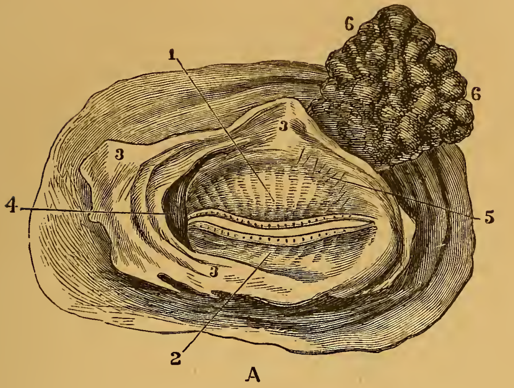
If either, or both eye-lids be examined internally, they will be found lined with a moist, very vascular membrane, the conjunctiva, which passes or is reflected from them upon the fore part of the eye-ball (Figs. IV. and V.), forming the outer covering of what is usually

called "the white." That portion of the conjunctival membrane which lines the lid presents on its surface numerous minute microscopic papillæ, which secrete the lubricating mucus of the eye, by means of which, whilst perfect apposition is preserved, the lid glides easily over the globe.

Between the conjunctival lining and the cartilages, but partly imbedded in the latter, lies a series of follicular glands, the "Meibomian" (Fig. V., A B). Each of these glands is composed of a number of minute bags, having their mouths directed to one common excretory duct, which has its orifice on the edge of the eye-lid (Fig. V., A 2, C 2). There are about thirty of these glands in the upper lid; rather fewer in the lower. Their office appears to be the secretion of an unctuous matter, by which all chance adhesions of the edges of the lids may be prevented.

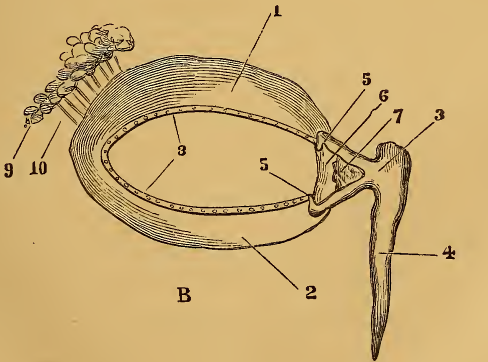
The conjunctiva, covering the entire front of the eye—including, in a modified degree, the cornea or transparent glass—is thrown at the inner angle, into a semilunar fold (Fig. V., C 3), the plica semilunaris. This is the rudiment of, or corresponds to, the third eye-lid, or nictitating membrane of many birds and animals.

Figure IV,.A.—Inner View of Eye-lids.



1, Upper Eye-lid. 2, Lower Eye-lid. 3, Lining Membrane. 4, Semilunar Fold. 5, Ducts of Lachrymal Gland. 6, Lachrymal Gland.

Figure IV., B.—Cartilages of Eye-lids, Lachrymal Sac, and Duct.



1, Upper Cartilage. 2, Lower Cartilage. 3, Lachrymal Sac. 4, Duct. 5, Lachrymal Puncta. 6, Semilunar Fold. 7, Caruncle. 8, Orifices of Meibomian Glands. 9, Lachrymal Gland. 10, Ducts.

Filling up the inner angle is the "lachrymal caruncle" (Fig. V., C 4), a reddish body composed of a collection of small glands, similar in structure and function to the Meibomian.

LACHRYMAL OR TEAR-CARRYING CANALS.

If either eye-lid be slightly everted, there will be perceived at the inner angle a minute perforation (Fig. IV., B 5; Fig. V., C 5), which, in the natural position of the lids, is directed inwards. These two perforations are the commencement of the lachrymal canals, into which the watery secretion, which is continually flowing over the eye, is taken by capillary attraction, conducted into the lachrymal sac (Fig. IV., B 3; Fig. V., C 1), and thence by the duct into the nose.

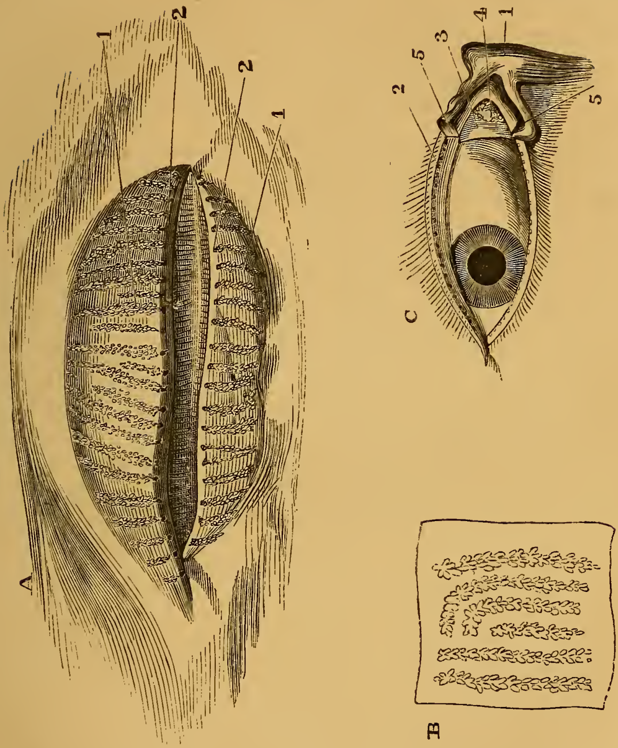
Lastly, we have the eye-lashes, beautiful both in appearance and use: these, arranged in triple row on each lid, by curving upwards and downwards, avoid all chance of interlacement. Thus it is, from the construction of the most important vital organ, to the arrangement of the most external adjunct to His creatures' convenience or happiness, we find the same God of love and wisdom in all, through all.

It has been remarked that the conjunctiva is reflected from the lids upon the ball. The white of the eye, which owes its appearance to the outer coat of the latter, is, therefore, only seen through the covering membrane, which, further, as it passes over the transparent cornea, becomes still more transparent. The structure of this portion of the membrane will be alluded to in conjunction with the microscopic anatomy of the cornea generally.

LACHRYMAL OR TEAR GLAND.

At the upper and outer corner of the upper eye-lid, a little above the superior border of its cartilage, it is possible for the anatomist to distinguish, and to thrust hairs into, the minute ducts of the lachrymal gland (Fig. IV., A 5, B 10). This body, which secretes the natural moisture of the eye at all times—the tears occasionally—is situated at the upper and outer angle of the orbit, and is about the size of a filbert (Fig. IV., A 6). It discharges its secreted fluid through the small ducts or tubes, eight or ten in number. As all are aware, this fluid is frequently discharged in great abundance; continually laving the surfaces of the

FIGURE V.—CARTILAGES AND THEIR CONNECTIONS.



A. 1, 1, *Meibomian Glands on inside of upper and lower eye-lids.*—2, 2, Their orifices on the edges of Eye-lids.

B. *Meibomian Glands*, enlarged.

C. *Eye.*—1, Lachrymal Sac. 2, Meibomian Orifices. 3, Semilunar Fold. 4, Lachrymal Caruncle. 5, Lachrymal Puncta.

lids and eye-ball, it assists their natural mucus to facilitate their easy gliding, and washes away whatever foreign matter may accidentally lodge upon or between them; being itself absorbed and carried off into the nose, by the beautifully complete little system of drainage already described (page 75). Few, perhaps, are aware of the considerable amount of fluid which is thus continually passed over the outer eye; but any one unfortunate enough to become the subject of obstructed lachrymal ducts or sac, is soon rendered sensible of how much he owes to the integrity of their apparatus, by the copious flow of tears over the cheek, and its consequent excoriation, and by the dryness of the corresponding nostril.

Although the lachrymal gland really lies behind, or is covered by the conjunctiva, it is so intimately connected with the outward and visible appendages of the eye—it is so completely one of its "tutamina," that it has been classed with the external apparatus.

How beautiful the combinations we have just examined! The lids, with firm, elastic, light, accurately-curved, and easily-moved cartilages; how obedient to the will; how quickly, without waiting for the will, closing on the

approach of sudden danger; or how gently, without effort or fatigue, folding over their charge during the hours of sleep; their edges fringed with those beautiful hairs whose curve is at once one of beauty and of use; and anointed from the elegant arrangement of the Meibomian glands! How perfectly does the conjunctival membrane cover both lid and ball, bearing upon its surface its own microscopic antifriction apparatus, and becoming transparent as glass where light is to be transmitted; and, lastly, how unfailing the ever-flowing fountain to keep all clear and bright by its constant stream, which its own tiny channels are sufficient to carry off, except on those occasions when excess of joy or grief, or of violent emotion, causes the overflowing of that fountain to relieve the inward pressure, and its stream to break the bounds of the water-courses!

CHAPTER IV.

Anatomy of Human Eye.

INTERNAL APPENDAGES—ELEVATOR MUSCLE OF UPPER EYE-LID—STRAIGHT MUSCLES OF EYE—OBLIQUE MUSCLES—FASCIA—VESSELS—NERVES.

CHAPTER IV.

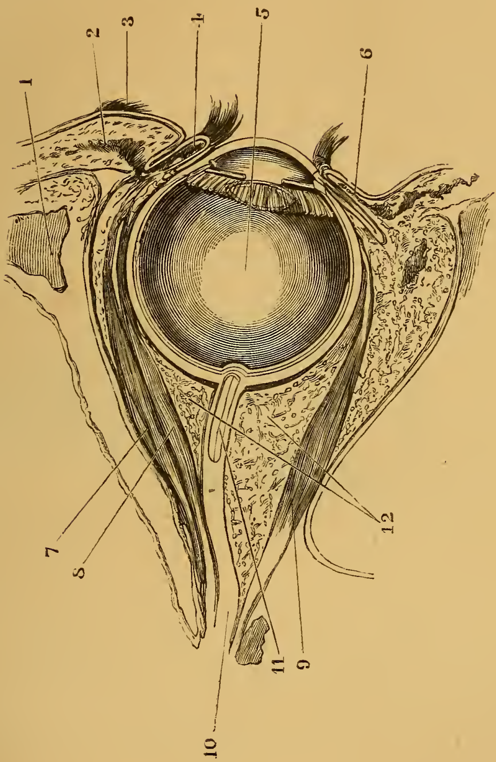
ANATOMY OF HUMAN EYE.

It has already been observed, that the natural position of the human eye-balls in their sockets is looking straight forward; in other words, with their axes parallel (Fig. III.), in contradistinction to the diverging axes of the sockets themselves. Where, as in the compound eyes of insects, the surfaces receptive of light and susceptible of vision extend, in many instances, over the larger segment of the sphere, the organ must afford a very wide range of sight, and be amply sufficient for all the requirements of the creature, even without movement. On the other hand, the angle of sight of the refracting eyes of vertebrated animals being comparatively limited, the exercise of the full utility of the organ requires for them the power of varied direction. It is amply provided for.

Seven muscles are contained within the human orbit; of these, six are devoted to the service of the eye itself, and one to the upper eye-lid, of which it is the elevator or opener. This long thin muscle (Figs. VI., VII. 1) takes its origin from the bone and optic sheath at the back part or apex of the cone, and, as represented, runs close underneath the arched roof of the orbit, to be attached to the upper lid, its action in opening which must be sufficiently obvious.

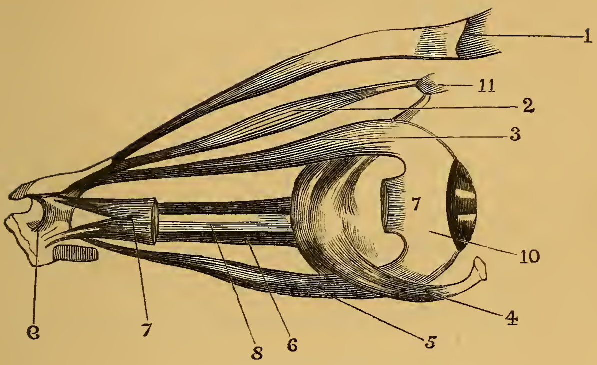
Of the six muscles of the eye-ball, four are straight or "recti" muscles (Figs. VI. 8, 9, VII. 3, 5, 6, 7); two are oblique (Fig. VII. 2, 4). The four straight muscles of the eye all take their origin from the bone and tendinous and fibrous tissues around it, at the apex of the conical cavity of the socket, and around the perforation which here exists for the passage of the optic nerve. In Fig. V., which represents a vertical section of the orbit and its contents, the superior and inferior straight muscles are seen running forward, the one under the roof, the other on the floor of the cavity. In Fig. VII., the same pair are also seen, along with the internal straight muscle—partly hid by the optic nerve—and along with the double origin, and the termination of the

Figure VI.—Vertical Section of Orbit and Eye-ball.



1, Upper bone of orbit. 2, Skin, &c., of forehead. 3, Eye-brow. 4, Upper lid. 5, Eye-ball. 6, Lower lid. 7, Elevator muscle of upper lid. 8, Superior straight muscle of eye-ball. 9, Inferior ditto ditto. 10, Optic nerve. 11, Central artery of optic nerve. 12, Fat in which the eye-ball is embedded.

Figure VII.—Muscles of Eye-ball.



1, Elevator muscle of upper eye-lid. 2, Superior oblique muscle of eye-ball. 3, Superior straight muscle. 4, Inferior oblique muscle. 5, Inferior straight muscle. 6, Internal straight muscle. 7, 7, Origin and termination of external straight muscle. 8, Optic nerve. 9, Bone at apex of orbit. 10, Anterior white covering of eye-ball. 11, Pulley for the tendon of superior oblique muscle.

external straight muscle, the body of which has been removed to permit a view of the parts just enumerated. These four muscles bear the same relation to the globe of the eye, each of them being attached to the outer coat at about two lines from the margin of the cornea. The expansion of their tendons used formerly to be described as furnishing an additional covering (tunica albuginea) to the fore part of the organ; that which, seen through the conjunctiva, constitutes the "white of the eye." This idea is now generally given up. A small "bursa" or elastic bag, containing a little fluid, is placed close to the eye-ball, under the attachment of each tendon, to prevent undue pressure in action.

The continued tonic action of these four muscles is calculated to retain the globe in a state of steady retraction within the socket. Their contraction altogether will obviously effect actual retraction; the action of one, singly, must, of course, incline the eye inwards, outwards, upwards, downwards, according to the muscle acting, whilst the diagonal of these directions must result from the simultaneous action of any contiguous pairs of muscles.

The superior oblique muscle (Fig. VII. 2)

presents, at least to the general observer, one of the most strikingly obvious instances of contrivance in the human form. Arising deep in the orbit, it passes, as represented, forward to its upper and inner angle, to a loop or pulley of fibrous gristle through which its tendon plays; its direction being thus completely changed, it passes downwards and backwards, to be fixed to the globe underneath the superior straight muscle.

The inferior oblique is the only muscle within the human orbit which does not take its origin from the apex of the cavity. It is short, arises from the inner portion of the orbital rim, and, passing outwards and backwards, is fixed to the outer and posterior portion of the eye-ball.

A moment's reflection will show how beautifully and simply the arrangement of muscular apparatus within the orbit is calculated to originate the various direct motions of the eye, and, at the same time, to provide for those rotatory movements of the sphere upon its axis, which, we shall see hereafter, are so essential for the perfection of vision. The antagonistic power, too, of these six muscles, must do much towards steadying the eye-ball, both

when at rest and in movement; but still further to ensure steadiness, "the globe, besides being embedded in fat (Fig. VI. 12), is suspended or slung in a capsule of fibrous tissue, with which it is in immediate contact." According to its describer, Mr. O. Ferral, this fascia or membrane extends from the cartilages of the eye-lids, back, over the ball and the optic nerve. It is perforated for the passage of the muscles, which, working through it as through pulleys, are thus prevented, when in action, from pressing injuriously either upon the ball itself, or upon the parts immediately around the nerve.

The remaining contents of the orbit, extraneous to the globe itself, are the blood-vessels and nerves. The cavity and its contents are mainly supplied with blood by an artery which enters from within the skull close on the outer side of the optic nerve. This large nerve has already been noticed as entering at the apex of the orbit, and continuing its course directly in the orbital axis, till it pierces the inner and posterior side of the globe.

"The marked manner in which the optic nerves terminate in the retina, the constant relation in size between them and the organ of

vision, the atrophy or wasting they suffer when the visual apparatus has been destroyed, the impairment or loss of vision which follows a morbid state of them, place it beyond all question that they are the proper conductors of visual impressions to the sensorium."*

The optic nerve is pierced before it enters the ball, by a branch from the artery of the orbit (Figs. VI. 2, VIII.), which, enclosed in the centre of the nerve, passes in to supply the retina or nerve lining of the eye with blood. In addition to the nerve of sight itself, three pairs of nerves entirely, and a fourth pair partially, are devoted to supply with nervous influence the contents of the orbit, including the eye-ball, which, deriving no other endowment from the optic nerve than the special sense of sight, requires the additional nervous supply for its general sensory, nutritive, and motor fulfilments.

Accordingly, a small ganglion (the ciliary) is formed on the outer side of the optic nerve, by the union of a branch from a motor with one from a sensory nerve, and from this union proceed the ciliary nerves of the eye-globe.

* Todd and Bowman's Physiology, Part III.

These nerves we shall learn more about as we proceed.

Even were all knowledge of that wonderful end absent, to which the perfect arrangements we have been examining are but the subservient means, the most unreflecting mind must feel that, in them, wise adjustment and bountiful provision had been made for some good purpose. How well these means subserve that end, it is trusted the following chapters will fully show.

CHAPTER V.

Anatomy of Human Eye—The Globe.

FORM OF EYE—SCLEROTIC COAT AND CORNEA—OPTIC NERVE—STRUCTURE OF CORNEA—ANTERIOR EPITHELIUM—ANTERIOR ELASTIC LAYER—LAMELLATED LAYER—POSTERIOR ELASTIC—POSTERIOR EPITHELIUM—CHOROID COAT—VESSELS—PIGMENT—CILIARY PROCESSES—RETINA—STRUCTURE—JACOB'S MEMBRANE—SENSIBLE SPOT—MACULA LUTEA—HYALOID MEMBRANE AND VITREOUS HUMOUR—CRYSTALLINE LENS—SUSPENSORY LIGAMENT—STRUCTURE—DIVISIONS—FISHES—CILIARY MUSCLE—AQUEOUS OR WATER CHAMBER—IRIS AND PUPIL.

CHAPTER V.

ANATOMY OF HUMAN EYE—THE GLOBE.

The form of the eye-globe is spherical; its general diameter, averaging about one inch, is increased from behind forwards by the prominence of the transparent cornea (Fig. VIII. 1), which occupies about one-fifth of the whole surface of the sphere. The eye-ball is usually described as possessing three principal tunics; of these, however, the outer can only strictly be considered as an investment, the others being rather laminæ of structure directly subservient to vision.

THE SCLEROTIC, OR OUTER COAT.

The sclerotic coat of the eye, as it is termed from its firm hard texture, is composed of inelastic white fibres, crossing one another at right angles; thus composed, it is endowed with great capability of maintaining its proper

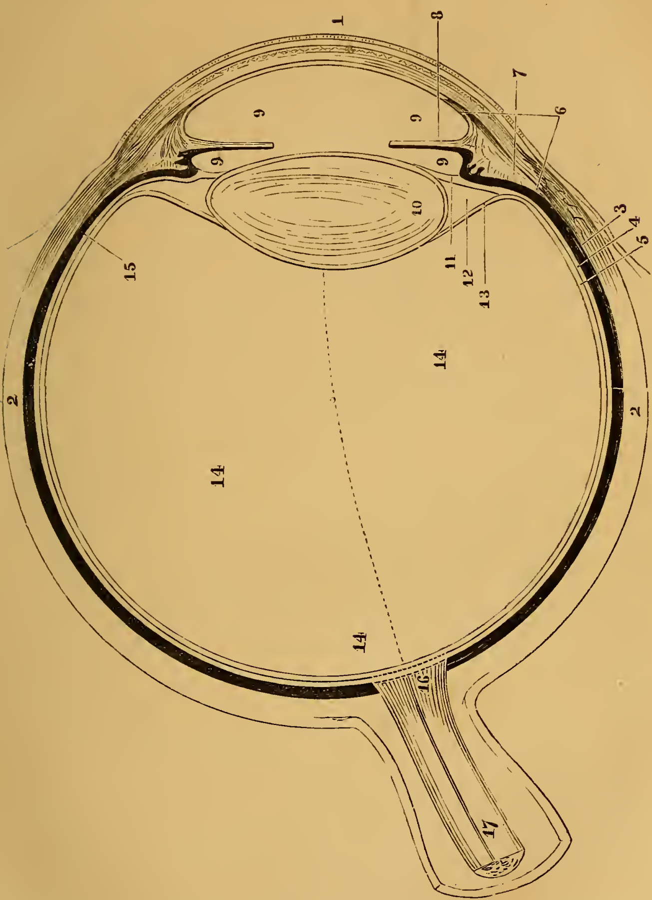
form—so much so, indeed, that even small pieces cut off retain that original curve of the tunic which is so essential to the perfection of vision. It is thickest posteriorly, and becoming thinner towards the fore part of the globe, again thickens slightly near the cornea.

THE CORNEA, OR GLASS OF THE EYE.

The cornea, or transparent glass of the eye, is generally described as being fitted or bevelled into the sclerotic coat, as a watch-glass into its case. In some measure the comparison holds good; but it is not to be imagined from this that the cornea is capable of being detached from the sclerotic around the bevelling: the two structures are intimately united. Some describe the cornea as a superaddition to fill up a gap, cut, as it were, in the sclerotic; others as the sclerotic itself, altered in structure. Both belong to the fibrous tissues.

Posteriorly, to the nasal side of the eye-globes, the sclerotic coat affords passage to the optic nerve, which here contracts considerably in diameter, and does not enter *en masse*, but with its fasciculi separated as they pass through a cribriform or sieve-like tissue thrown across the opening, its outer investing sheath becom-

FIGURE VIII.—HORIZONTAL SECTION OF LEFT EYE-BALL.



1, Cornea, showing its Laminæ. 2, Sclerotic Coat. 3, Choroid Coat, prolonged over Ciliary Processes and Iris. 4, Retina, ceasing at (15 15) the Ora Serrata. 5, Hyaloid Membrane, inclosing Vitreous Humour and attached (13) to posterior portion of capsule of lens. 6, Ciliary Muscle, attached in front to the Cornea, externally to the Sclerotic, internally to the Choroid, Ciliary Processes, and Iris. 7, Ciliary Processes. 8, Iris. 9, 9, Posterior and Anterior Aqueous Chamber. 10, Crystalline Lens inclosed in its Capsule. 11, Suspensory Ligament of Lens commencing at (15) the Ora Serrata. 12, Canal of Petit, formed by Hyaloid Membrane posteriorly, Suspensory Ligament anteriorly, and by rim of Lens. 13, Hyaloid Membrane. 14, Vitreous Humour. 15, Ora Serrata, the termination of the Retina, the commencement of the Ciliary Processes, and of the Suspensory Ligament, corresponding also to attachment of Ciliary Muscles. 16, Cribriform Fascia of the Sclerotic through which the Optic Nerve enters the Eye. 17, Optic Nerve with its central artery.

ing at the same time continuous with the sclerotic. "Though the nerve is moveable on its entrance, it is always fixed firmly at the inner surface of that aperture, where the retina commences." Further, the sclerotic is pierced in various parts, more especially posteriorly, by smaller nerves, and by vessels passing to the interior of the globe.

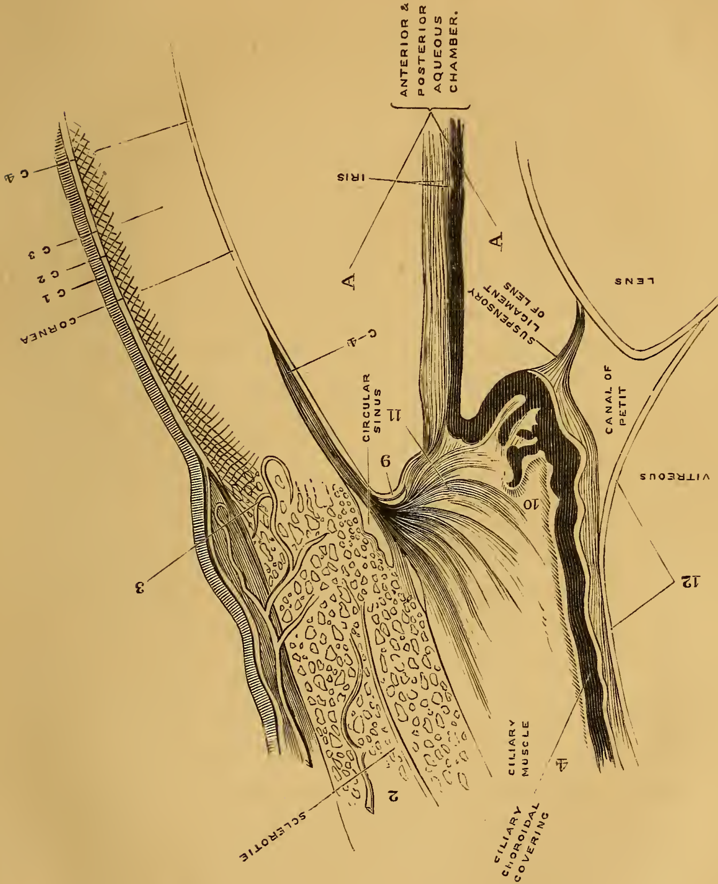
The transparent cornea, looked at superficially, appears as one homogeneous glassy body; examined carefully, and with the aid of the microscope, it is found to be remarkably compound—so much so, indeed, that although already examined by many and careful observers, recent researches have elucidated interesting and beautiful points of structure, previously unknown.

The cornea may now be considered to be made up of five different layers of structure (Figs. XV. A, XVI. A)—the outer, or epithelial, the anterior elastic, the laminated, the posterior elastic, and the posterior or aqueous epithelial. The outer epithelial coat may be considered as a continuation of the conjunctiva or membranous eye-covering, which here becomes remarkable for its assumed transparency. Figs. XV. A, XVI. A, represent the appear-

ance of thin sections of the cornea under high magnifying powers; and 1, 1, the appearance and structure of the outer and conjunctival epithelium, which consists of three layers of remarkably transparent cells, the outer imbricated, that is, arranged like tiles on a roof, the inner cylindrical or tapering (Fig. XV. B). The continuity of the conjunctival membrane covering the cornea, with that covering other portions of the eye, and indeed with the skin generally, is demonstrated in the case of snakes, which, in casting their skins, cast with them this outer case of the cornea structure of the eyes.

Figs. XV. A 2, XVI. A 2, represent the anterior elastic lamina, or layer, of the cornea, of Mr. Bowman. "Its thickness in the human eye is from $\frac{1}{1200}$th to $\frac{1}{2000}$th of an inch;" it extends over the whole surface. "It is a continuous sheet of homogeneous membrane," perfectly transparent and glassy, without appearance of internal structure; "it is very elastic." Not the least interesting feature of this layer, is its mode of fixature to the cornea proper, or lamellated cornea, immediately beneath. This, as represented (Figs. XV. A 3, XVI. A 3), and as described by Mr. Bowman,

Figure IX.—Enlarged View of the Connections of the Ciliary Body and Parts adjacent.



The Conjunctiva is shown (C 1) covering the Cornea. The Anterior Elastic Lamina (C 2) braced down to Middle Lamina, and passing into fibrous attachment with Sclerotic. The Middle Lamina (C 3) continuous with Sclerotic. The Posterior Elastic (C 4) giving commencement to Ciliary Muscle (11) and Fibres to form the Pillars (9) of the Iris. The connections of the Ciliary Muscle shown, anteriorly to Cornea, outwardly to Sclerotic, inwardly to Choroid and Ciliary Processes (10), and by these to Suspensory Ligament of Lens, connected also to the Iris.

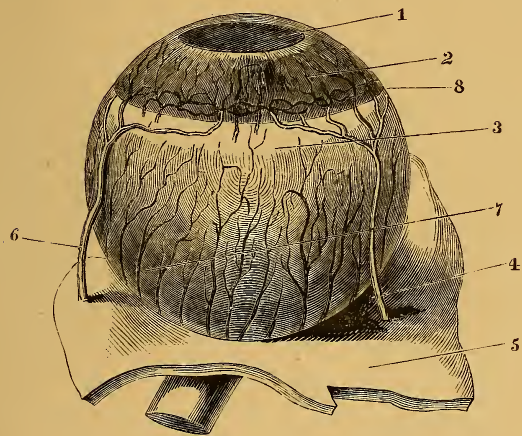
is effected by means of fibres passing from its inner surface down into the substance and among the lamellæ of the cornea proper; these fibres cross one another at right angles. At the edge of the sclerotic, the lamina appears to resolve itself entirely into such fibres, which here take a more oblique direction, and passing into the former tissue—the sclerotic—become continuous with it. The evident purpose of this anterior elastic lamina, is the preservation of the proper degree of curvature of the cornea so necessary for distinct vision. It is impossible to conceive a structure more especially adapted, more exquisitely arranged, for its offices than this, till lately unknown, tissue.

The cornea proper, lamellated or middle layer of the cornea (Figs. XV. A 3, XVI. A 3), constitutes the great mass of the structure; it is tough, transparent, very unyielding, and composed of numerous layers or lamellæ, not extending in one sheet throughout, but running one into another as it were. About sixty of these layers may be counted in any single section. The interesting discovery was made by Mr. Bowman, that the interstices between these layers, instead of being simply, as might at first appear, irregular spaces, were entirely

filled with a series of regular tubes (Figs. XVI. B, XVIII. B). Mr. Bowman considers the use of these tubes to be connected with the permeation of the thick mass of the cornea, "by the more fluid portions of the blood which alone have access to it;" no blood-vessels, even of the smallest size, passing beyond a short distance from its margin in the healthy state (Fig. XVII. A). At the point of junction with the sclerotic, the lamellated cornea becomes continuous with that tissue (Figs. VIII. 3, IX. 3). The change in the disposition of the tissue is represented in Fig. XVIII. A, which shows the sclerotic running into the cornea, the tubular interstices cut across.

Behind the cornea proper is placed the posterior elastic layer (Fig. XV. A 5), closely resembling the anterior elastic, but differing from it in being much thinner and not braced down to the middle layer by those fibrous attachments which, highly requisite in the former, would here be evidently superfluous, thus affording one other instance of the universal rule evident throughout creation, that its Author, omnipotent in resource, never wastes. The office of this layer is evidently the same as that of the anterior, to assist in preserving the

Figure X.—Choroid Coat and Arteries.



1, Pupil. 2, Iris, appearing convex from lying upon the Lens. 3, Ciliary Muscle. 4, 6, Ciliary Arteries. 5, Sclerotic Coat turned back. 7, Choroid Coat and its Arteries.

curvature of the whole; at its junction with the sclerotic, this lamina resolves itself into fibres, the course and destination of which will be adverted to hereafter.

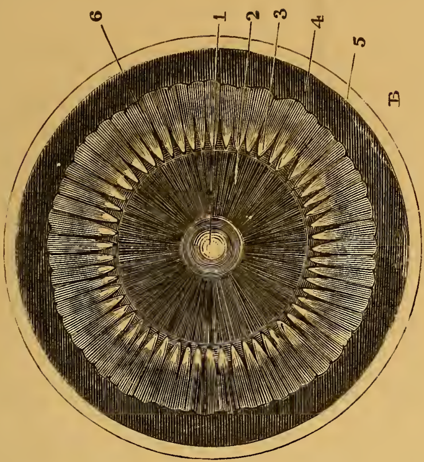
The posterior elastic lamina is lined on its inner side by the fifth corneal layer, the thin posterior epithelium (Fig. XV. A 6, E F).

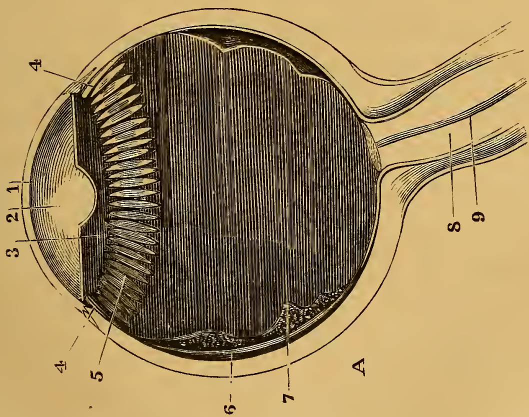
It would evidently interfere with distinct vision, did vessels large enough to convey red blood traverse the cornea throughout; consequently we find that, in the healthy state, no vessels of such size pass beyond half a line from its margin, thus avoiding all chance of interference with visual rays entering the pupil. The vessels which do advance over the margin of the cornea (Fig. XVII. A) are all derived from the conjunctiva and are superficial; others, derived from the deeper or choroid lamina, turn back just before reaching the margin. The cornea is dependent for its nutrition upon the colourless and more fluid portions of the blood, which probably transude the tube system of Mr. Bowman. This system is all-sufficient in the healthy state. In certain conditions, however, of disease or of reparative action, arteries and veins conveying coloured blood are projected across the transparent me-

dium in a wonderfully short space of time, and as speedily withdraw themselves when the cause of their formation has ceased and their mission been accomplished.

How great the variety of structure, how evident the careful design, how exquisite the adaptations in this small portion of our frame, this atom of creation. The natural philosopher employs the sense of sight to explore the height and depth of structure in the very organ through which that sense is conveyed; he sees upon one portion of its components—the tiny structures of the cornea—care the most unwearied, skill the most magnificent, have been lavished without superfluity, and all in keeping, from the least to the greatest. Must he not feel that the care which made, will also sustain in perfection and beauty as long as that Divine Providence deems well? Will he not raise the mind from the things of earth? Will he not feel in the exploration of these his Creator's works, in the examination of the "fearfully and wonderfully" constructed human frame, that He who made so beautiful a dwelling for the living tenant within, and endowed that tenant with the heaven-sent gift, the immortal powers of using that habitation

Figure XI.—Internal View of Choroid Coat, &c.





A—1, Cornea. 2, Anterior Aqueous Chamber. 3, Iris. 4, Ciliary Muscle. 5, Ciliary Processes. 6, Sclerotic Coat. 7, Choroid. 8, Optic Nerve. 9, Central Artery.

B—1, Pupil. 2, Posterior Lamina of Iris, usually called the Uvea, showing its converging folds. 3, Ciliary Proccsses. 4, Choroid. 5, Sclerotic. 6, Ora Serrata.

for his rational, his intellectual, and his spiritual weal, is but preparing him—if he will be prepared—for that higher state of existence, compared with which, this, with all its elaborate organization and harmonious working, with our "perfect vision," is but seeing "through a glass darkly."

THE CHOROID, OR COLOUR COAT.

If the outer coat of the eye, consisting of the sclerotic and cornea, be now removed or turned aside, the second lamina, usually called the choroid coat, is exposed. It appears externally of a deep chocolate colour, and flocculent; its pigmentary matter being easily detached, clings to the fingers. Near the optic nerve, this coat adheres to the sclerotic; but except at this point, the connection is extremely slight, only by a sort of web of remarkably fine cellular tissue.

Anteriorly, about a line from the margin of the cornea, the choroid appears to be covered exteriorly by a gray, softish-looking structure (Figs. X. 3, XII. 6), the ciliary body or muscle, which, anteriorly, forms a common point of union for the sclerotic and cornea, the choroid

and iris. The choroid is very vascular; its blood-vessels pass in and out, through the sclerotic, at various points, but chiefly posteriorly (Fig. XIII. 3). The distribution of the arteries is shown in Fig. X.; that of the veins is peculiar: their courses, directed to certain common points of union, form beautiful curves over the choroidal surface (Figs. XII. 4, XIII. 5); within the larger vessels, the finely divided capillaries form a vascular network (Fig. XIX. F).

The black pigment so characteristic of the choroid coat of the eye is produced by, and contained in, a series of minute cells. These form on the inner surface a distinct layer, are hexagonal in form (Fig. XIX. A D E), and arranged like a tesselated pavement. They are, however, likewise distributed among the blood-vessels and their branches, and then become prolonged in various irregular forms (Fig. XIX. B C).

A little in front of the optic nerve, the sclerotic is pierced by the nerves which are to supply the iris and surrounding parts; they run between it and the choroid, and become flattened so as to lie compactly (Fig. XII.)

If the inside of the choroid be now ex-

Figure XII. – Choroid Coat. Nerves and Vorticose Veins.

1, Sclerotic turned back. 2, Pupil. 3, Iris. 4, Posterior Veins of Choroid. 5, Ciliary Nerves. 6, Ciliary Muscle.

amined, it will be found perfectly black (Fig. XI.), and, anteriorly, at a line corresponding to the commencement of the ciliary body, assuming a remarkably beautiful appearance (Fig. XI. A 5, B 3), being thrown, as it were into a regular series of triangular folds, the ciliary processes. These commence at a waved line, the "ora serrata," at first merely as streaks, but gradually become marked into distinct plications, the black pigment lying in greatest abundance between the folds. The illustration will convey a better idea of the position and appearance of this beautiful ring than any description. The ciliary bodies are extremely vascular; their points or anterior portion just overlap, without touching, the lens, and project slightly into the aqueous chamber of the eye, behind the iris, with which they are connected (Figs. VIII., IX., XI.)

THE RETINA, OR NERVE LINING.

The retina, or inner coat of the eye, is the expanded sheet of nervous matter derived from the optic nerve; it is the essential portion of the visual organ, the mysterious link between material appearances and mental impressions,

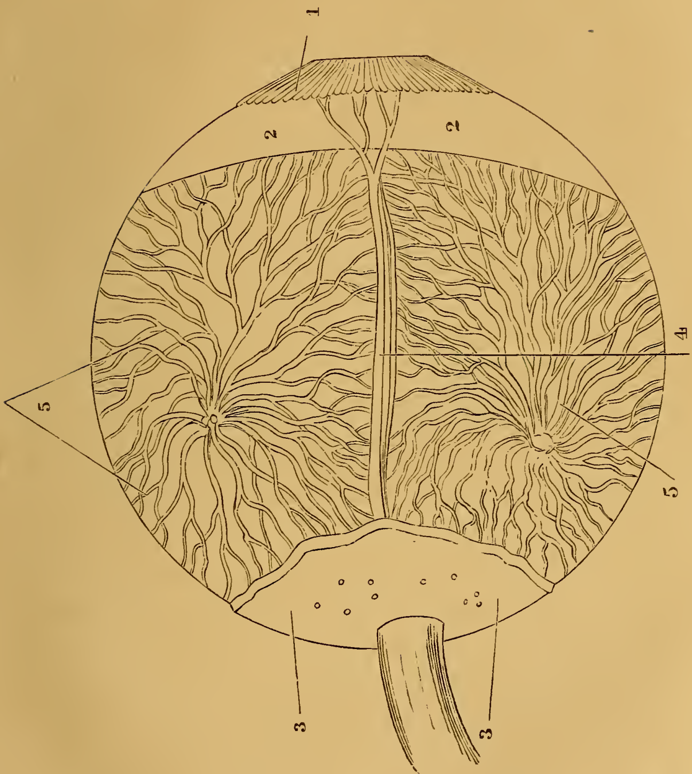
without which, or in a diseased state of which, all other arrangements for vision, however perfect, must be futile. The eye may seem as lustrous as ever, its depths as clear, but if the retina or its nerve fail, all is dark, "and knowledge from one entrance quite shut out." This nerve blindness, "amaurosis" of physicians, is the "gutta serena" of the blind Milton.

> "These eyes, though clear
> To outward view of blemish or of spot,
> Bereft of light, their seeing have forgot;
> Nor to their idle orbs doth sight appear."

The retina lines the entire back portion of the eye, terminating anteriorly at the "ora serrata," or ciliary commencement (Fig. XIV. B); from this point, a non-nervous lamina, marked by the plaitings of the ciliary processes, extends forward to the edge of the iris.

In a living, or perfectly fresh eye, the retina is transparent, but soon after death acquires an opacity somewhat resembling that of ground glass. Its composition is complex. Fig. XX. exhibits its various layers of nervous matter, as they appear in a magnified section; the special object of these arrangements is not understood. The remarkable outer layer (Fig.

FIGURE XIII.—VORTICOSE VEINS OF CHOROID.



1, Iris. 2, Ciliary Muscle. 3, Portion of Sclerotic, pierced by small Vessels and Nerves. 4, Long Ciliary Nerve and Vein. 5, Vorticose Veins of Choroid.

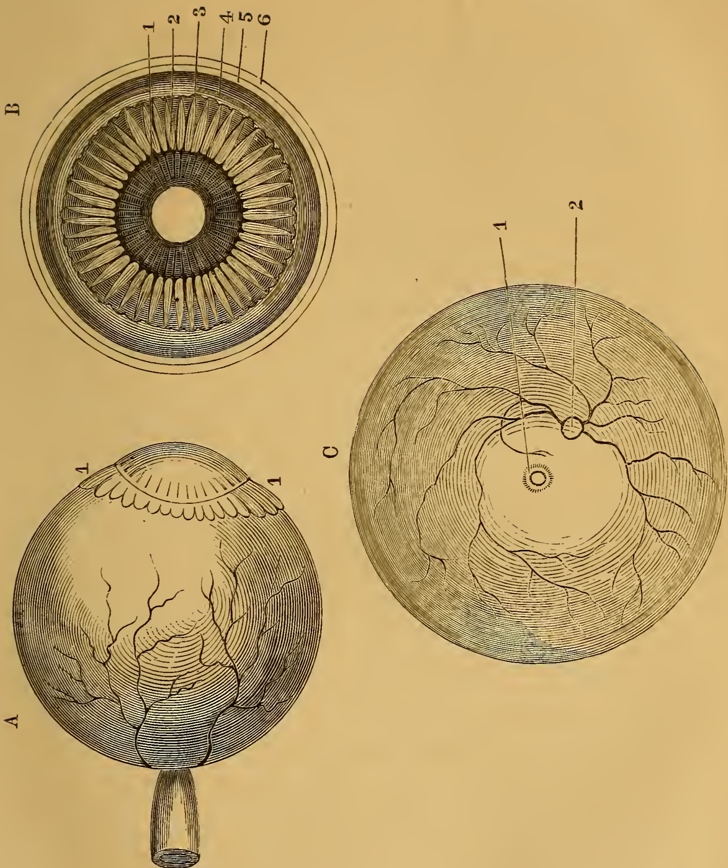
XIX. B 7), frequently described separately as the membrane of Dr. Jacob (Fig. XIX. A 2), lies between the colouring pigment of the choroid and the other portions of the nervous sheet. Its structure is, at the same time, singular and mysterious, being made up of innumerable "rod-like" bodies (Fig. XIX. B 8), hooked or clubbed at the extremity; seen with the naked eye, this membrane looks like the finest film. The inner layers of the retina appear composed of arrangements of nerve, vesicles, and tubes, along with—most internally—the extremely fine vascular expansion of its blood-vessels (Fig. XIX. B 3).

Posteriorly, the retina presents two spots (Fig. XIII. C 1 2). The entrance of the optic nerve, with its central artery (2), lies of course to the nasal side of the axis, and is quite insensible as regards vision. From this point, both the nervous and vascular expansions may be said to have their origin. The other spot of the retina (Fig. XIV. C 1), or "spot of Soemmerring," found only in man and some animals which have the axes of the eyes parallel, lies exactly in the centre of vision. It is of a yellow colour, and about $\frac{1}{24}$th of an inch in diameter; it is the only part of the retina on

which distinct vision can exist, but its exact use is unknown. The interestingly complex structure of this little spot has been described from a minute examination of the human eye very shortly after death—a fact of great consequence—by Dr. Grube, of Konigsberg. "With the naked eye, it was at once easily seen that the macula lutea—yellow spot—was not a little raised above the surface of the retina. On placing it and the part around it under a microscope, magnifying 300 times, and compressing it but slightly, the macula lutea presented exactly the appearance of shagreen; elegant rounded particles gradually tapering towards the middle, which were smaller the nearer they were to the centre, and there not more than one-fourth or one-fifth of the size of the medullary corpuscles on the surface of the rest of the retina, were arranged close together and with great regularity, like rays passing from the centre to the circumference of the spot,"* in the form of a star. It is remarkable that the gray fibrous layer of the retina immediately in connection with the optic nerve, and apparently a continuation and modification of

* Microscopic Journal, 1841.

Figure XIV.—Retina.



A, Exterior View of Retina and its Arteries—1, The Grooves of the Ciliary Processes.

B, Interior View of Retina, anteriorly—1, Iris. 2, Ciliary Folds. 3, Ora Serrata, where the Retina terminates. 4, Retina. 5, Choroid. 6, Sclerotic.

C, Interior View of Retina, posteriorly—1, Macula Lutea, Yellow Spot or Foramen of Soemmerring. 2, Insensible Spot of Retina, the entrance of the Optic Nerve and Artery of the Retina.

its nerve tubules, is the only nervous element present at the insensible spot of the retina. It may be justly concluded from this, that the vesicular layers are necessary for the sensation of sight. "The incapacity of vision at the entrance of the optic nerve seems to be essential to the mode of junction of the retina with the nerve, since it appears to be the chief reason why the nerve was not made to enter in the axis of the eye." Had it done so, of course vision would have been completely spoiled.

HYALOID MEMBRANE, AND VITREOUS OR GLASS-CLEAR HUMOUR.

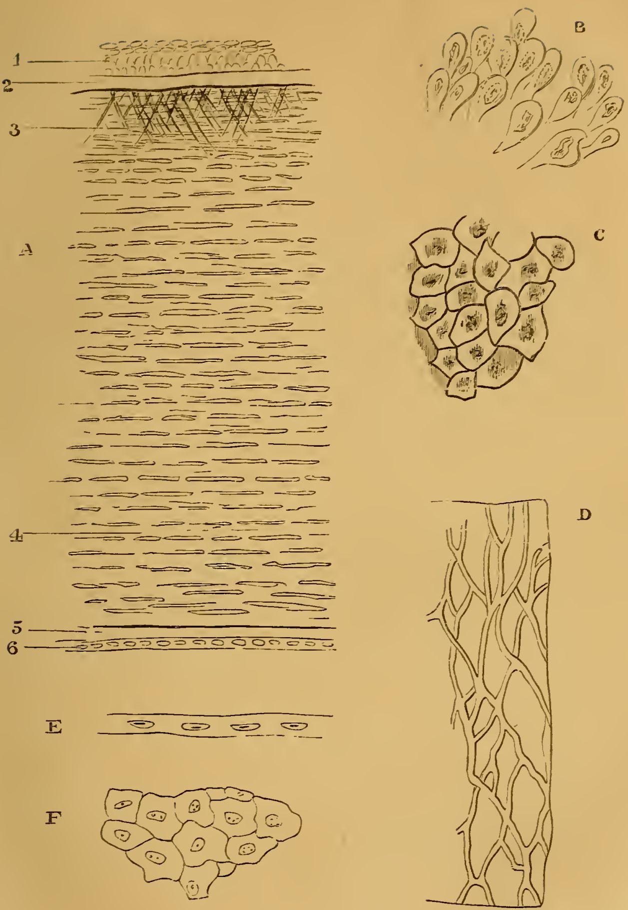
The inner surface of the retina is covered by the transparent membrane, the Hyaloid, the only separation being a layer of translucent cells. This membrane contains within it the vitreous humour of the eye, that exquisitely transparent, jelly-like substance which makes up about four-fifths of the contents of the ball. The structure of the vitreous humour is still undecided; being composed for the most part of water, the fluid, according to some, is kept *in situ*, by laminæ connected with the hyaloid membrane, and radiating from the centre, like

the divisions of an orange; by others the layers are said to be concentric. Whatever the structure, the effect is a comparatively firm, most transparent substance, in the fore part of which lies imbedded the crystalline lens.

THE CRYSTALLINE LENS.

The crystalline lens, of firmer, denser consistence than the vitreous humour, appears perfectly transparent. It is situated just behind the pupil, and is imbedded in the anterior part of the vitreous, which slightly overlaps its rim. It is closely enveloped in a transparent, elastic capsule, which is thickest anteriorly. In addition to being imbedded in the vitreous, the lens is sustained in position by its own suspensory ligament (Figs. VIII. 11, IX.), described by Mr. Bowman as commencing at the ora serrata, lying underneath the ciliary body, between it and the hyaloid, and leaving the former in front, the latter behind, passing to its attachment on the fore part of the lens, a little below its rim. The same author represents the hyaloid membrane as passing underneath the ciliary body, between it and the vitreous, and turning back as represented (Figs.

Figure XV.—Cornea.



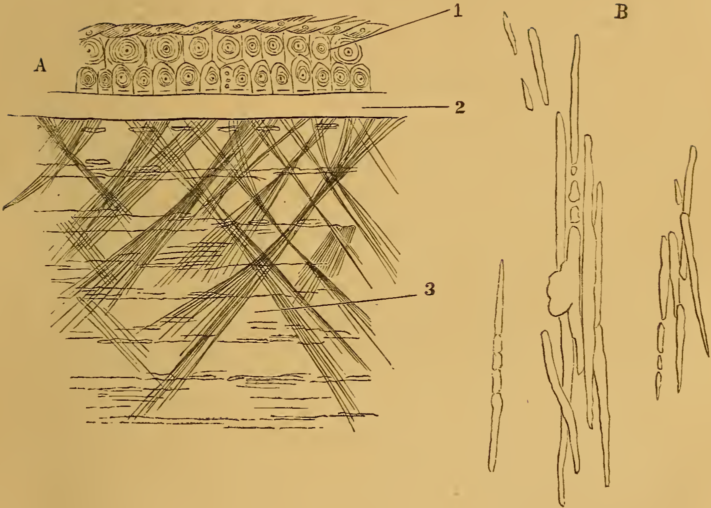
A, Appearance of Magnified Section of Cornea—1, Conjunctival Epithelium. 2, Anterior Elastic Lamina, with, 3, its Fibres passing into 4, Middle or Laminated Cornea, or Cornea proper. 5, Posterior Elastic Lamina. 6, Posterior Epithelium. E, The same Posterior Epithelium, magnified in section. F, in front. B, Cells of Section of Anterior or Conjunctival Epithelium magnified. C, the same in front. D, Elastic Fibres of Posterior Elastic Lamina.

VIII., IX.), to be affixed to the back of the lens capsule. The effect of this arrangement is the formation of a small canal—that of Petit—all round the rim of the lens. The consequence of this, as regards vision, will be considered in a future page.

The crystal lens, though apparently homogeneous in structure, is, like the cornea, when minutely examined, found to be most beautiful, most elaborate. Its shape is oval, a double convex lens; its width about one-third of an inch, its thickness about one-sixth (Fig. XXIII. E); its sides unequally curved, the posterior being the more convex. The substance of the lens is comparatively soft towards the outside, but gradually increases in density and firmness as the centre is approached. Between the body of the lens and its capsule a layer of transparent cells is interposed (Fig. XXIII. A). The body of the lens is capable of being separated into layers or lamellæ, like the coats of an onion (Figs. XXII. C, XXIII. F); these layers are, however, limited by certain determinate lines, which radiate from the centre. The primary number of these lines seems to be three (Fig. XXII. B). They occur on both sides of the lens; those, however, on the pos-

terior surface, instead of being opposite to those on the anterior, lie between them, as it were (Fig. XXII. B); thus, if the lines 3 were prolonged, they would reach the circumference at 1, the corresponding lines on the other side would come upon it at 2. The direction of these primary lines in the lens would seem to differ in different animals; in man, though the primary division of three is recognisable, they quickly branch out (Fig. XXII. A), and thus render the other arrangements more complicated. Moreover, the laminæ of the body of the lens are beautifully constructed of flat, toothed fibres (Fig. XXIII. C G), laid side to side (Fig. XXIII. B). This arrangement is remarkably evident in the lens of the cod-fish, in which it was first discovered (Fig. XXIII. B C). It is not so strongly marked in man, but is sufficiently distinguishable. The toothing is deepest on the superficies, and becomes less as the centre of the lens is approached. These toothed fibres are all arranged with reference to the primary divisions radiating from them (Fig. XXII. B). The necessity, the object, for this elaborate structure is beyond our ken; we only know that it is, and we can feel that it does not exist in vain. Man's words can

FIGURE XVI.—CORNEA.



A, Highly Magnified View of Section of Cornea—1, Anterior Epithelium Cells of Cornea. 2, Anterior Elastic Lamina. 3, Laminated Cornea and Fibres from Anterior Elastic Lamina. B, Cornea Tubes of Mr. Bowman.

add but little to heighten the reverential admiration with which the mind contemplates all that is cared for in the perfect construction of this little body, which, to the superficial observer, presents no more trace of structure than a fragment of common glass.

CILIARY BODY OR MUSCLE.

It has been observed that the choroid coat of the eye appears, externally, about a line from the sclerotic and corneal junction, to lose its black colour, and to become of a gray, semi-transparent tint; this is the result of its becoming covered by the ciliary body or muscle. Deriving fibres from, and attached to the posterior elastic lamina of the cornea, this body—now without doubt proved to be muscular—extends backwards, between the sclerotic and the choroid and ciliary processes, till it gradually thins off to its termination, at a line corresponding to the ora serrata (Figs. VIII. 6, IX.) Thus we have the keystone of the eye, as it may be called, connected anteriorly with the cornea, outwardly with the sclerotic, inwardly with the ciliary bodies, and their lining choroidal epithelium, and by means of

them with the vitreous humour, its hyaloid containing membrane, and, necessarily, with the suspensory ligament of the lens; lastly, with the iris. These manifold connections must give the ciliary muscle most important influence over certain of the finer adjustments of the optical apparatus.

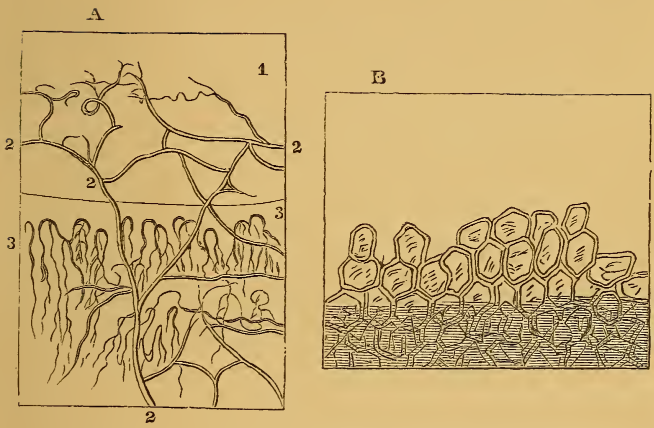
AQUEOUS OR WATER CHAMBER.

Between the fore part of the lens and the posterior layer of the cornea is the chamber of the aqueous humour, containing, as its name implies, a few grains' weight of colourless fluid, little more than water. This fluid, in conjunction with the cornea, in the first place, exerts a powerful refractive effect upon all rays which penetrate the latter; and, in the second, forms a fit medium in which the iris, which divides this chamber into anterior and posterior, may float and easily move (Figs. VIII. 9 9, IX. A A).

THE IRIS.

The iris, the most inimitable of optical contrivances, is named from its appearance and

Figure XVII.—Cornea.



A, Magnified View of Portion of Cornea—1, Cornea; 2 2, Superficial Vessels from Conjunctiva, advancing a short way over its margin. 3 3, Deeper Vessels of Sclerotic, turning back before reaching margin of Cornea. B, Front View of Conjunctival Epithelium magnified.

varied hue. Its form and colours are familiar to most, or may soon become so by ten minutes' study before a mirror. Suspended like a curtain, and floating in the aqueous fluid, it forms the coloured moveable background to the cornea; varying in size and appearance according as it contracts or enlarges the pupillary aperture (Fig. XXI. B 1), which is formed in it, a little to the nasal side of its exact centre. The iris may be regarded as a prolongation or proceeding from the choroid, which not only supplies its vascularity, but is at the same time continued over it posteriorly from the ciliary bodies. The posterior coloured layer of the iris is frequently named the uvea; and Dr. Jacob describes this as covered, and the colouring pigment separated from the aqueous fluid by an extremely fine membrane, also continued from the ciliary bodies. The remaining portions of iris structures are peculiar to itself.

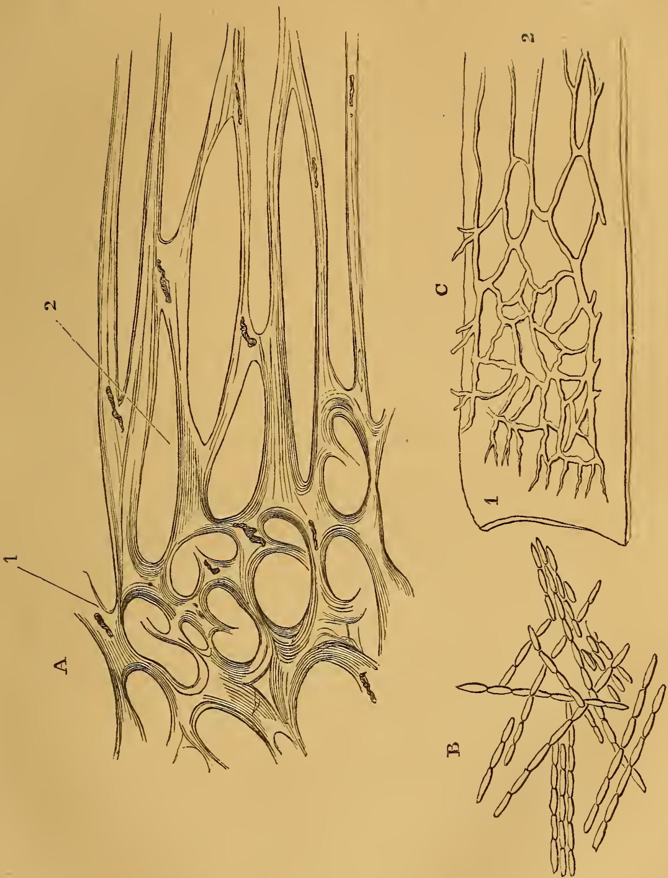
The circular iris has its outside or peripheral attachment to the fore part of that common bond of union, the ciliary body (Figs. VIII., IX., XI., XXI. B). Posteriorly, it has the epithelial connection with the choroid, already mentioned; anteriorly, with fibres, the pillars of the iris, which proceed from the posterior

lamina of the cornea, and curve round the rim of the aqueous chamber (Figs. VIII. and IX. 9).

The posterior layer of the iris has the appearance, when the pupil is contracted, of being thrown into folds, converging to the edge of the pupillary aperture. These converging folds (Fig. XI. B 2) have been considered* as a provision for allowing a more abundant deposit of pigment. The anterior surface of the iris being coloured and mottled, obscures in a great measure the disposition of its muscular fibres. From the periphery, or outer margin of the iris, a number of slightly elevated lines converge towards the pupillary aperture, and, coalescing, form a peculiar knotted-like ring, about one-tenth of an inch from its margin (Fig. XXI. B 2). Between this ring and the edge of the aperture are a number of converging striæ, which communicate with each other. In addition to the converging fibres, others, lying in front of them, but circular, or encircling the pupil, are also to be detected. Observers ascribe to these the power of contracting the pupil, as to the

* Dr. Jacob.

Figure XVIII.—Cornea.



A, Magnified View of Continuation of Sclerotic Fibrous Tissue into Cornea proper.

Vertical Section. 1, Sclerotic. 2, Cornea. B, Corneal Tubes of the Ox. C, Elastic Fibres, commencing in Posterior Elastic Lamina at 1, running to Iris, 2.

former that of dilating it; by some, however, the contraction is partly attributed to turgescence of the vessels, caused and maintained by contraction of the muscular fibres of the iris itself, or of the ciliary muscle.

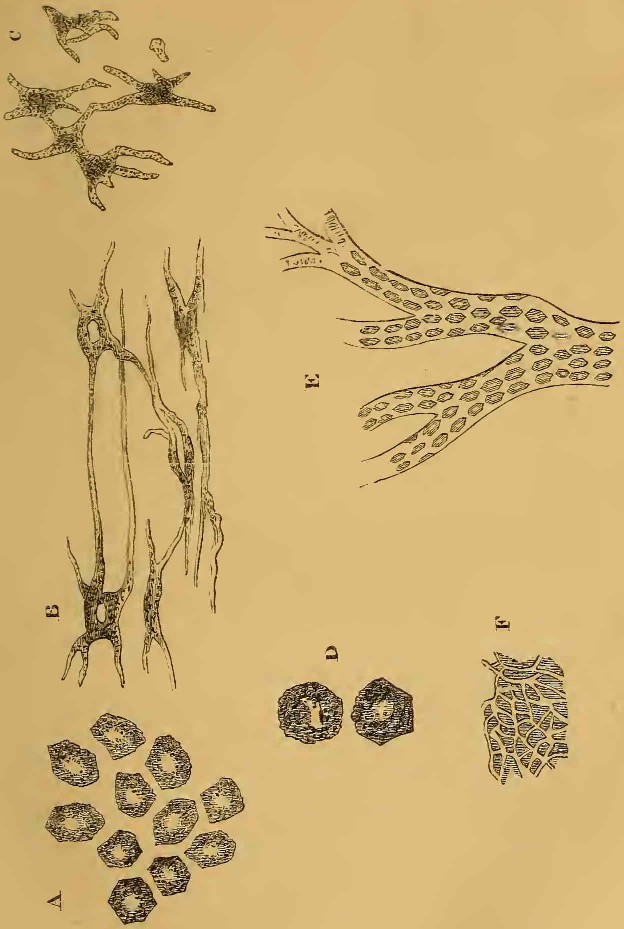
The iris is vascular, and is supplied by the ciliary arteries (Fig. X.), which form a kind of branched ring around it. The nerves of the iris (Fig. XII.) are abundant; piercing the sclerotic, as already described, they become flattened as they pass between it and the choroid, to be distributed to the iris and ciliary body.

The most remarkable and wonderful attribute of this beautiful structure is its immense power of contraction and dilatation. Under some circumstances, and in some conditions of the system, as exposure to strong light, or narcotism from opium, the pupil is diminished to an aperture scarcely larger than the head of a pin, by the spreading of the whole curtain over its dark expanse; under other circumstances, more especially under the influence of certain drugs, as belladonna or henbane, the iris curtain is drawn up, almost to disappearing, and the full size of the black-looking pupil displayed. The variations of the pupil are

from one-third to one-twentieth of an inch in diameter.

Commencing with the sclerotic coat of the eye, we have seen the adaptation of its inelastic, firm tissue to be the investing, form-preserving, and protecting tunic of the delicate structures within. The cornea, with its various layers, all telling of wise purpose, has been examined; it yet remains for us to consider how its combination with the other transparent, refracting media, the aqueous, the crystalline, the vitreous, constitutes a beautiful optical instrument, of which the aberrations are corrected by the moveable iris, the adjustments regulated by the ciliary structures, and the superfluous light absorbed by the dark lining of the choroid. Thus far we can go—we can follow the rays of light till, directed in obedience to known laws, they image upon, in, the complex substance of the nervous sheet of the retina the things of the external world; but here we stop. Our microscopes can reveal the complex and curious organization of this nervous expansion, but they cannot carry our mortal vision over the great gulf which lies between the things of matter and the existences of spirit. We know that we see; but how we,

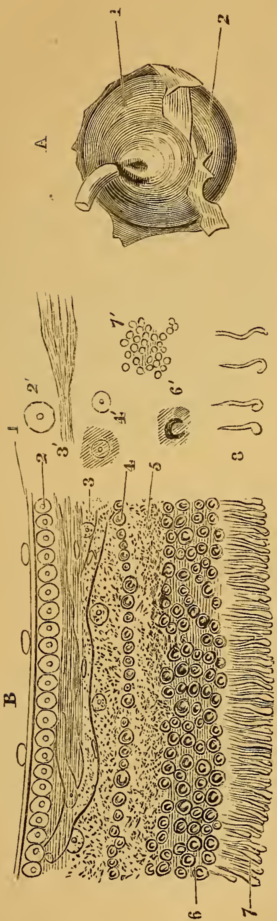
Figure XIX.—Pigment Cells of Choroid.



A, Hexagonal Cells of Choroidal Epithelium. D, the same, more highly magnified. B C, Irregular Pigment Cells, lying among Vessels of Choroid. E, Arrnagement of Pigment Cells on the Coat of a Vein in Eye of Ox. F, Capillary Vessels of Choroid.

our real selves, our conscious spirits, look through the windows of the soul upon the face of creation, the microcosm upon the macrocosm, we cannot tell. How much is contained within that little "one-inch" globe! How much that tells of wisdom, infinite to design; of power, omnipotent to execute; of love, unbounded to bestow!

Figure XX.—Retina.

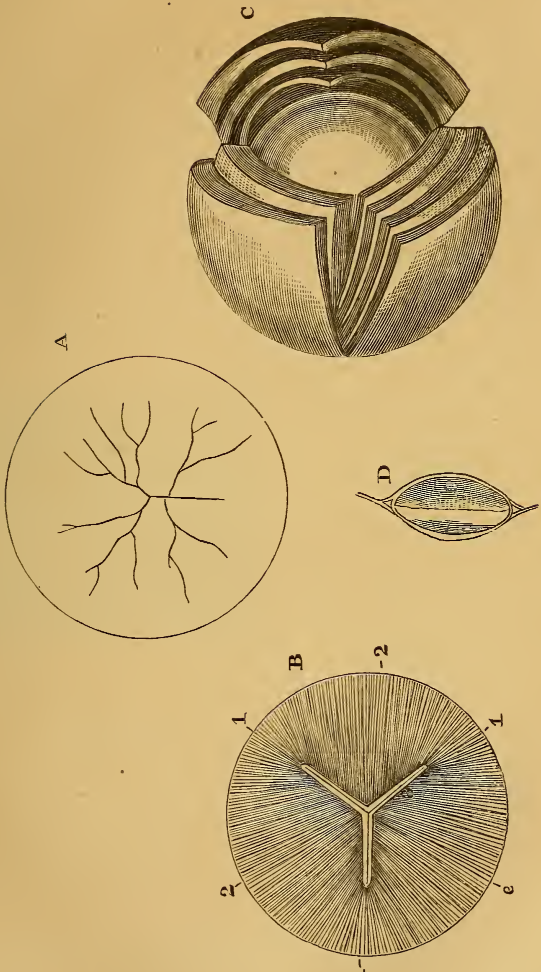


A 1, Retina. 2, Jacob's Membrane, partly detached. B, Magnified Section of Retina and Hyaloid Membrane—1, Hyaloid Membrane. 2, Layer of Transparent Cells between it and Retina. 2′, Single Cell. 3, Vascular and Fibrous Lamina of Retina. 4, 5, 6, Granular and Vesicular Layers. 7, Jacob's Membrane. 7′, as seen in front. 8, Detached Rods of Jacob's Membrane.

Figure XXI.—Iris.

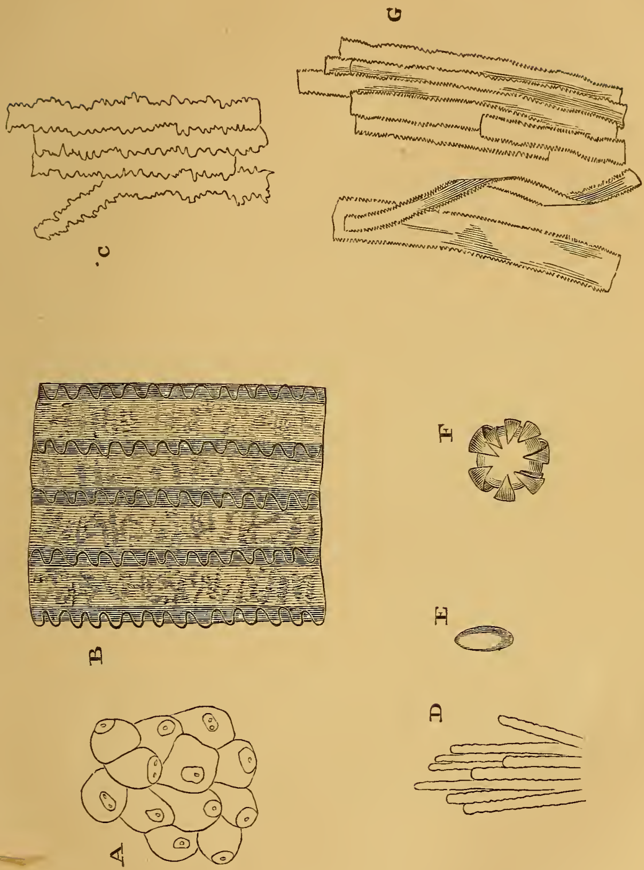
A, Corona Ciliaris. B 1, Pupil. 2, Knotted Circle running round Iris. 3, Iris. 4, Ciliary Muscle or Ligament.

Figure XXII.—Crystalline Lens.



A, The Primary Divisions, branching in Human Lens. B, Lens of Sheep; three Primary Divisions of Radiating Fibres. C, Division of Lens into Laminæ. D, Lens and Capsule enlarged.

FIGURE XXIII.—STRUCTURE OF LENS.



A, Cells between Capsule and Body of Lens, magnified. B, Adaptation of Toothed Fibres of Lens. C, Deeply-toothed Fibres from Lens of Cod-fish. D, Fibres of Lens with merely Sinuous edges. E, Human Lens. F, Human Lens separated into Laminæ. G, Toothed Fibres from Lens of Ox.

CHAPTER VI.

Physiology of Human Vision.

ESSENTIALS OF AN ORGAN OF VISION—COURSE OF RAYS ENTERING EYE—CORNEA AND AQUEOUS—LENS—VITREOUS—RETINA—CHOROID—IRIS, ITS ACTIONS; PERFECTION AND BEAUTY—LENS—REFRACTING POWERS—VITREOUS—CHOROID—ABSORPTION OF LIGHT—VISION—FOCAL CONVERGENCE—ADAPTATION—DISTANT VISION—MYOPIA—NEAR VISION—PRESBYOPIA—RANGE OF VISION—VISION WITH TWO EYES—OPTIC COMMISSURE—DOUBLE VISION—PERSPECTIVE DISCRIMINATION—APPRECIATION OF DISTANCE—CHROMATIC CORRECTION—REFLECTIONS ON EVIDENCE OF CREATIVE POWER AND WISDOM.

CHAPTER VI.

ON THE PHYSIOLOGY OF HUMAN VISION.

The essential component of an organ of vision is the termination, more or less enlarged or expanded, of an optic nerve, specially endowed with the faculty of conveying to the sentient creature the sensation of sight. Along with the nerve two supplementary additions are perhaps invariably present, a transparent covering or cornea, partly intended for protection and partly for refraction, and a colouring matter, generally black, for the absorption of superfluous light. In the human eye these component parts occur (Diag. IX.)—a nervous expansion, lining a dark chamber, glazed anteriorly by the cornea. This simple arrangement would, however, be insufficient to admit of the clear and accurate vision requisite for man; accordingly, those exquisite adaptations

of structure which have already engaged our attention are associated with it. It remains to consider how that structure and adaptation conduce to the one great end of perfect sight.

Rays proceeding from external objects, and entering the human eye, have to traverse four, or, considering the cornea and aqueous as one, three transparent media, before reaching the retina. The cornea and aqueous, the crystalline lens, the vitreous humour (Diags. IX. and X.) As these media are all of different density, and present curved surfaces to the impinging rays, they must necessarily exert considerable refractive power upon their course and direction.

A certain proportion of the luminous rays which impinge upon the cornea are reflected back; the greater number, however, enter the eye, and between the curved surface of the transparent covering and the lens, traversing in the interval the fluid of the aqueous chamber, suffer their first and greatest refraction (Diags. IX. and X.) By this they are made to converge considerably towards the axis of the eye-globe. Reaching the anterior convex surface of the denser lens, this convergence is increased by the additional refraction. Lastly, emerging from the lens into the comparatively

Diagram IX.—Optical Apparatus of Human Eye.

A A, Cornea and Aqueous; first Refracting Media. B, Lens; second Refracting Medium. C, Vitreous; third Refracting Medium. D, Position of Receptive Surfaces of Retina and Choroid. E, Diaphragm formed by Iris; interior lined black. *a*, Ray reflected from Iris.

rarer vitreous, the refraction, now from the perpendicular, continues the inclination in the assumed direction, and preserves it, until the rays are absorbed by the black pigment of the choroid, after traversing the transparent retina. In accordance with the optical laws which regulate refraction, and as a glance at Diag. X. will show, the necessary effect of these alterations in the course of the rays is to form inverted images of external objects upon the retina.

The considerable refraction which rays undergo on entering the cornea and aqueous, tends to converge them strongly through the pupillary aperture, the amount admitted depending, of course, upon its state of contraction or dilatation, according to which more or fewer are intercepted, absorbed, or reflected, by the curtain of the iris.

There can be no question that one principal object of this beautifully contrived "diaphragm" is to counteract the confusion which otherwise must result from spherical aberration, in consequence of rays entering the eye through the marginal portions of the crystal lens, whilst at the same time, in conjunction with, and assisted by, the eyelids and eyebrows,

it regulates the amount of light admitted to act upon the delicate retina.

In ordinary daylight, whilst objects at a moderate distance are viewed, the iris maintains the pupil in a state of moderate contraction, sufficient light being admitted to render the images of objects, formed by the central rays, perfectly distinct. In obscure light, on the other hand, retraction or drawing up, as it were, of the iris, and consequent enlargement of the pupillary aperture, is requisite, that such additional light may be introduced into the interior of the eye as will compensate for its diminished intensity, even at the expense of some distinctness of definition by the admission of marginal rays. The effect of this regulating power of the iris is often practically exemplified in the case of those who are becoming the subjects of cataract, and in whom the opaque spot, formed in the centre of the lens, often completely obscures vision, as long as the pupil is contracted under the influence of bright daylight, but are enabled to see with tolerable distinctness when, in the dusk of the evening, it expands sufficiently to admit rays through the clear marginal portions of the lens.

Some have imagined that the rapidly sensitive movement of the iris must result from the action of light directly upon its own surface, and not, as it assuredly does, from sympathy with the retina. The error of this opinion has not only been shown by experiment, but is evident from the fact that when, either in consequence of disease or accident, the retina of one eye has become insensible to luminous impressions, light directed upon that of the other will excite action in both irides at the same moment, notwithstanding that of the injured eye had previously remained immoveable under the influence of strong light impinging directly upon itself. Doubtless, then, the movement of the iris is regulated by, and takes place in obedience to, effects exerted by luminous rays upon the retina expansion of the optic nerve; its message of sensation conveyed to the brain, being there instantaneously converted into one of motion, and telegraphed back through its own peculiar nerve, testifies the fact of its delivery by the alteration of the pupil. Thus, the iris of the injured eye partaking of the influence exerted upon the retina of the sound one, sufficiently evidences the community and interchange of influences

which must take place at the central station, as it may be called, in the brain.

Looking at the objects fulfilled by the iris—its perfect adaptation to the ends for which it has been created, as it floats free in the aqueous humour, ever ready, like a watchful sentinel, to guard, or as a faithful attendant to serve, its charge within—it is impossible to imagine a structure more fitted for the purposes in view. None, perhaps, in the vast range of the world's creation, exhibits more strongly, in its simple perfection, the wide gulf which intervenes between the living creations of the Almighty and the dead imitations of man. Combining both use and beauty, the rainbow curtain of the "sun-bright eye" confers much of their expression upon those organs whose "heavenly rhetoric" will sometimes persuade where the tongue would fail—which, by their "bend," speaking the silent superiority of mind over mind, compel the obedience of the irresolute to the stronger will, or "awe" the fiercest animal, till it shrinks away from the look of man, and tacitly yields him the dominion assigned him by his Maker.

LENS.

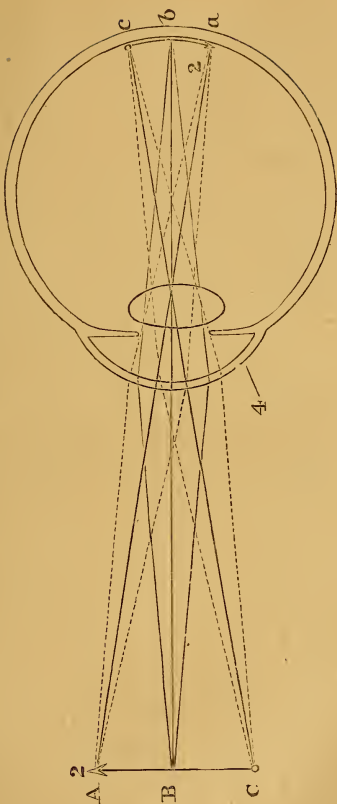
All rays which penetrate the pupillary aperture necessarily impinge upon the lens (Diags. IX. and X.), and in doing so again become refracted. Central rays, and those falling near the centre, even though obliquely, do not of course undergo the same change of direction as those further removed. What is the object—and it is certain there is one—attained by the elaborate workmanship displayed in the structure of the crystal lens, is not at present fully known. It is, however, easy to understand why it should be denser in the centre than at the margin; the provision against spherical aberration furnished by the iris diaphragm is, by this, further assisted, and the increased refraction of the circumference being in a measure compensated for by the diminished density of structure, the whole of the transmitted rays are more nearly collected into one focal point.

Passing from the lens into the vitreous, the rarer body, the rays, again suffering a slight refraction as they traverse the latter, enter the retina, their final destination, ere they are absorbed by the dark choroid behind.

Rays, of course, form their image directly in the axis of the eye, and exactly upon the yellow central spot of the retina—we only know the fact (Diags. IX. and X). The image, moreover, is inverted, and must be curved, in accommodation to the curve of the eye itself, being by this, at the same time, rendered more distinct. How it is that one image, formed inverted upon the retina of the bodily eye, is seen by the mental eye erect, we cannot say. Many learned and ingenious explanations have been attempted. The fact is not more wonderful than that we see at all, and probably its explanation is equally hid from human ken.

Without some special provision for their removal, the rays of light which enter the eye to form the sight-picture, must inevitably be reflected back in various directions within the globe, with the effect of occasioning great visual confusion. This special provision we find in the dark light-absorbing choroid, which lines the whole interior, even over the back of the iris to the verge of the pupil.

DIAGRAM X.



Refraction of Rays entering Human Eye, and forming a Reversed Image.

VISION.

Distinct and perfect vision of any ordinary object requires it to be so placed before the eye, as that the rays from it being converged by the refracting media of the organ, may come to a focus exactly in the retina. A B C (Diag. X.) represent three points of an object, from which rays proceed to enter the eye. The central ray of B suffers, of course, no refraction, that of A and C but slight; these central rays, however, determine the line of direction to which the more diverging rays from the same points, which pass through the circumference, are deflected. It is evident, that if the object viewed be placed exactly at the proper focus suited to the particular eye, that is, so that the refracted marginal rays shall intersect their perpendiculars at the same points, mutually and relatively, the result will be a perfectly defined image of the object viewed, formed in the retina. It is no less evident, that should the eye remain in *statu quo*, and the image be moved to any extent in a straight line, either nearer to it or further away, perfect definition must be lost: in the

former case, the focal intersection would be thrown to a point behind or beyond the retina (Diag. IV.); in the latter, it must take place in front of it. In either case, the image being indistinct, "on the supposition that the eye admitted of no adjustment to distance, there could be only one distance at which objects could be seen perfectly."

Every individual has his own focal distance at which he can see more clearly than at any other. The general average may be reckoned at ten inches. As all know, however, the eye can be adapted to view, perfectly, objects much further removed; we can raise the eyes from a book to the distant landscape, and, almost instantaneously, from seeing the letters or engraved lines of the one distinctly, view the distant objects of the other with perfect clearness. The nature of the power of adaptation, thus evinced, has long exercised the thoughts and investigations of physiologists. It would here be out of place to enumerate all the explanations offered; suffice it, that the most probable is that which ascribes the adaptation to the muscular power of the ciliary body, by which, when near objects are to be viewed, the lens is slightly advanced towards the cornea; the

latter, probably being rendered somewhat more convex by the same power (acting through the attachment to the posterior elastic layer), not only converges the rays more quickly, but also must slightly increase the length of the eye's axis. A glance at Figs. VIII. and IX. will show how, as the suspensory ligament of the lens adheres to the ciliary processes, these being advanced by the ciliary muscle, the ligament and lens must necessarily be also advanced to the cornea. Were it not for the canal of Petit, the strain would be exerted upon the whole vitreous body, instead of, as it is, upon the lens only. When distant objects are looked at, the relaxation of the muscular power permitting the lens to be retracted by the natural elasticity of the parts, and the cornea to become flatter, refraction will be diminished.

If, when an object is placed in the exact focus of the eye, light be sufficiently abundant to permit such contraction of pupil as will exclude all possibility of confusion from spherical aberration, vision will be perfect and accurate; nevertheless, large objects at a distance may be seen with perfect clearness, the pupil being dilated, and even if the amount of light be less. In the former, vision will embrace the

distinct definition of detail in the object viewed; in the latter, only the more marked outline. Between the two there must be every gradation. At the extremes, however, the size of the pupil is markedly different, and is evidently connected with visual adaptation of the eye. This adaptation of the eye in man is for the most part involuntary; some individuals, however, acquire the power of exercising it at will,* and in these it is said the adaptation is accompanied by voluntary contraction or dilatation of the pupil. "It is probable, however, that we may have pretty distinct vision, when the foci of the 'pencils' of rays are at some distance beyond or before the retina, and that the larger the object the greater the latitude of aberration, before we are sensible of any indistinctness."

Although most eyes may be enabled to view distant objects with tolerable clearness, the range of distinct vision nearer than ten inches is very limited; at half the distance confusion of outline occurs, and nearer still, a minute object becomes invisible. The focal

* Dr. Roget has stated, in his "Physiology," his possession of this power.

distance for distinct vision, of course, varies somewhat in different persons; when, however, it is much diminished, the individual is considered to have "short sight," a condition of eye depending partly on undue convexity of cornea, by which the rays are converged so rapidly, that the image is formed anterior to, instead of in, the retina. The defect is rectified, naturally, by diminishing the distance between the eye and the object of sight, but as this is neither convenient nor possible at all times, artificial correction, by glasses which slightly disperse the rays before they reach the eye, is more generally resorted to. Short sight may, however, in some measure be due to want of adapting power in the eye, as well as to convex cornea; this is more probable, from the fact that children's eyes are more convex than those of adults, and yet vision is perfect.

In the eyes of aged persons, the opposite condition to the above more generally prevails; the cornea becomes comparatively flat, its refractive power diminished, and the image is thrown posterior to the retina. Convex glasses, which assist the convergence of the rays, are, of course, the appropriate remedy.

If observation be directed to different objects around, the eye naturally inclines towards them, moved by its own muscular apparatus, so as to throw the image upon the central portion of the retina, where it will be most clearly and distinctly defined. The one point of sight is distinct, other objects are seen, but it is undefinedly; being thrown out of the visual axis, they are formed upon the less sensitive portion of the nervous sheet. The range of vision conferred upon the eye by the action of its own muscular appendages has been calculated at fifty-five degrees, on an average, in every direction, more extensive outwardly than inwardly; it is, of course, increased by the use of both eyes.

It is matter of experience with all, that whilst the body is conveyed rapidly along, as in a carriage, and the eye kept fixed in one position in the socket, various objects appear to pass by in more or less confused sequence according to the rapidity of the motion; but that if any one object attract the attention particularly, it is possible to "follow" it with the eye. Further, that the same may be done in movement of the head simply. In the first place, the confused succession is due to a

number of different images being formed consecutively upon the retina, and, if with great rapidity, one impression not having subsided before another succeeds it; the more vivid impression, moreover, frequently obscuring the weaker one, or even annihilating it altogether. The counteraction to this effect, by which the eye is made to follow the moving object, and to keep it fixed on one spot of the retina, is effected by the action of muscles of the eyeball, more particularly by that of the oblique. The provision is one of the most important as regards vision, and is constantly being called into action during the various changes of position our bodies are momentarily subject to in waking life.

Hitherto, attention has been given to vision with one eye only. When that with both visual organs comes to be considered, the question presents itself, how is it we see only one image when two must be formed, one in each eye? This question is probably involved in that respecting the mysterious connection which links the material retina with the sentient mind; it affords, however, considerable scope for reasoning and hypothesis, founded upon the peculiar arrangements of the optic

nerves, more particularly at their commissure or partial junction within the skull. At this point (Fig. III.) the principal and central mass of fibres from each side of the brain crosses over to the opposite side and eye, comparatively few of the outer fibres of the nerve being continued on to the eye of their own side. In consequence of this arrangement, the retina of the inner side of one eye, that of the outer side of the other, derives its nerve tissue from the same side of the brain; and as images formed eccentrically in the retina must necessarily fall on the outer side of one retina, on the inner side of the other, we recognise a beautiful provision for conveying to the same nervous root, or sentient origin in the brain, the double impression blended into one whilst traversing the common conductor. The effect produced by images of external objects being formed in non-corresponding points of retina is easily shown by pressing one eyeball gently, so as to throw its axis out of correspondence with that of the other; objects are seen double. Internal causes which disturb the consensual action of the visual organs have a similar effect. The double vision of intoxication is proverbial; the poet represents Orestes in his

anger as "seeing a double Thebes, and two suns blazing in the firmament."

Mr. Wheatstone has shown that the provision for combining two material images into one sensation gives also the power of perspective perception. When objects are viewed at such a distance that the eye-axes are parallel, the power is not exercised; but when a solid object, such as a cube, is looked at near, in a certain position, it requires the use of both eyes to see that it is solid. For instance, a square box, placed at a little distance in front of one eye, the other being closed, will look like a flat surface until the other eye is opened, when it at once appears in relief. This fact renders it impossible, in drawing, to represent an object—such as a house—to appear otherwise than as a flat surface when the view is taken from a short distance in front. A person with only one eye remedies the loss of perspective discrimination by the muscular movements and change of position of the head, and probably also by experience and mental association.

Our appreciation of distance in vision is evidently the result of education and experience. The infant will frequently grasp at objects far removed from reach, and adults

who have had their sight opened by operation, after being blind from birth, require some time before they learn the relative distances between themselves and external objects; and even those whose sight is usually perfect are apt greatly to miscalculate distance, where, as at sea, or on extensive plains, there are no intermediate objects to assist the discrimination.

Lastly, there has to be overcome in the eye the tendency to "chromatic aberration," found in all dioptric media. Some observers maintain that this is not entirely corrected in the eye, and that the images formed in it are actually surrounded by coloured fringes, but to so small an extent as not to be observable. However this may be, there certainly exists no inconvenience from it in the exercise of the sense of sight; and it is probably nearly, if not entirely corrected by the combinations of different lenses contained within the eye. Valée considers that the vitreous humour "is composed of layers of different density, and that the rays of different colours are thus brought into one line."*

We have reviewed the requisite optical laws, have examined with sufficient minuteness the

* *Brit. and Foreign Medico-Chirurg.*, vol. xi., p. 250.

arrangements and structure, general and microscopic, of the human eye, and have considered how these arrangements and structures, exactly adapted to the requirements of optical phenomena, conduce to the formation of the perfect vision we enjoy. One conviction forces itself upon the mind—a conviction that only the most determined opposition to all argument, the most wilful blinding of the eye of rational intelligence can shut out—that if there is a God who made the sun to shine, who said that light should be, that He made also the eye. Upon such as resist the evidence—the revelation written by the finger of the Almighty, in his handiwork—argument is wasted; with such it is indeed *arare littus;* the thankless sandy soil yields no return, and the first wave of pride obliterates the loose half-formed furrow which unwilling conviction had drawn. In vain do we point to the laws of general refraction, and to their fulfilment in the focal refraction of the eye; to the iris, the regulator of light and corrector of aberration; to the dense centre and less dense margins of the lens arranged for a similar purpose; to the absorbing power of the choroid, and to the delicate expansion of the retina, with its various layers;

to the focal adaptation to distance, and to the correction of chromatic aberration; to the consensual action of both sight-globes; all is nought. Let those who doubt, ponder upon the provision for acting, and also for preventing; look, and look again—examine, think, and then ask themselves what improvement they can suggest in this one little work of creative power and wisdom: will not the answer of every rightly constituted mind be—None would attempt it but "the fool," who "hath said in his heart there is no God?"

It is evident that structure and arrangement the most complete must be insufficient to confer clear vision, without perfect transparency of the dioptric media; at the same time, we know that all organized structures require a constant supply of nutrient elements from the blood. The admission of vessels carrying red blood being, however, impossible in any way across the line of vision, the difficulty is obviated by the transudation of the transparent tissues, by the more liquid and colourless portions of the vital fluid; in the cornea, probably by the tube system of Mr. Bowman; in the lens and vitreous, by filtration from the extremely vascular ring of ciliary processes.

CHAPTER VII.

Comparative Anatomy and Physiology of the Eye.

INVERTEBRATE ANIMALS—SENSIBILITY TO LIGHT OF LOWEST ANIMAL TRIBE—OCELLI OF MEDUSA AND STAR-FISH—POLYGASTRIC AND WHEEL ANIMALCULES — PARASITES — BARNACLES — ANNELIDA, OR WORM TRIBE—CENTIPEDES—EYES OF INSECTS—COMPOUND AND SIMPLE MODE OF VISION—SPIDER TRIBES—CRUSTACEA, OR CRAB TRIBE—SIMPLE—AGGLOMERATED — COMPOUND — MOLLUSCA, OR SOFT-BODIED TRIBE.

CHAPTER VII.

THE EYE. ITS COMPARATIVE ANATOMY. INVERTEBRATE ANIMALS.

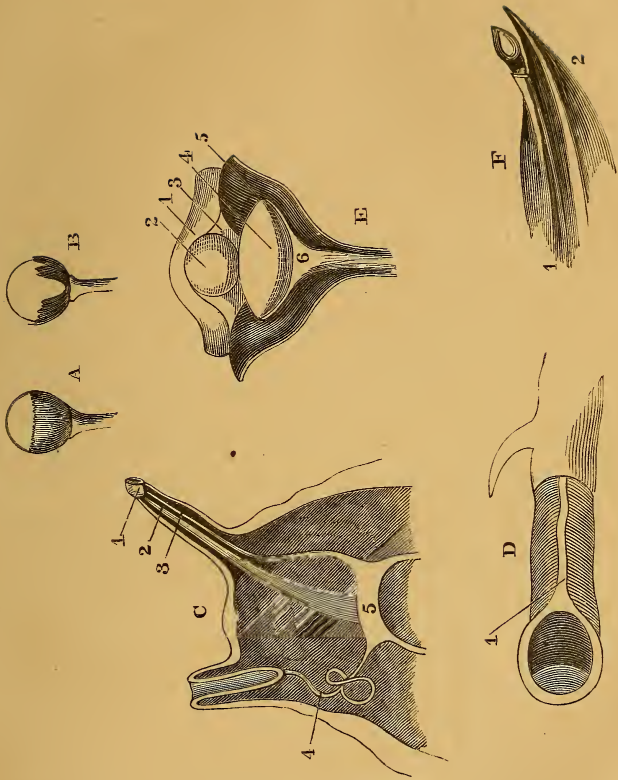
The lowest tribes of the animal kingdom, the sponges and polyps, appear to possess simply such general sensibility to the agency of light as we may conclude is sufficient for the requirements of their humble state of existence. In a species of locomotive medusa, organs to which the sense of vision may be attributed first make their appearance, and similar simple "ocelli" are observable in some of the star-fishes, albeit, in the majority of the species belonging to these classes of animals, nothing resembling an eye has been discovered. If, however, these creatures do not possess the sense of sight, its absence is, to them, fully compensated for by the extreme delicacy and acuteness of their general sensation, which, by making them aware of the slightest vibra-

tions occurring in the surrounding media, must, we can conceive, afford cognizance of all external relations, sufficient for the limited and peculiar wants of the being. Indeed, Cuvier considered that the sense of touch alone is so acute in zoophytes as to be sensible to light.

In the extremely minute but more highly organized polygastric and wheel animacules, the red spots, or "eye-dots," first described by Ehrenberg, are now generally considered to be organs of vision, some are even described as containing a lens. In the parasitic animals, the visual ocelli are more highly developed, and in the still higher class, the barnacles, are possessed as long as an organ of vision can be useful; that is, whilst the young animal is capable of swimming about in the water, but become obliterated shortly after it fixes its habitation, and when the loss is supplied by the development of the exquisitely sensible ciliated tentacula.

In the annelida, or worm class, eyes become sufficiently developed to be capable of definite demonstration. Muller describes them as exceedingly simple in construction (Fig. XXIV. A B), merely "the expansion of the terminal

Figure XXIV.



A B, Simple Ocelli of Annelida. C, Tentacula of Snail, showing—1, Eye; 2, Retraction Muscle; 3, Optic Nerve; 4, Optic Nerve thrown into folds by retraction of tentaculum; 5, Cerebral Ganglion. D, Enlarged view of Eye of one of Snail tribe. E, Enlarged view of Eye of Scorpion: 1, Cornea; 2, Spherical Lens; 3, Aqueous Chamber; 4, Vitreous; 5, Choroid; 6, Optic Nerve and Retina. F, Eye of one of the Crustacea, on a peduncle; 2, Orbital Sheath.

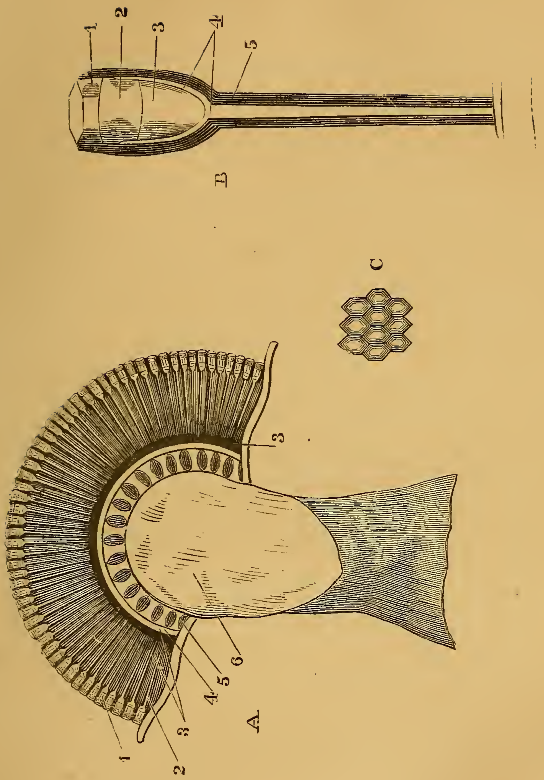
extremity of a nerve, spread out beneath a kind of cornea formed by the delicate and transparent cuticle, and behind this a layer of black pigment." In the common leech, which belongs to this class of animals, the eyes, ten in number, "are ranged in a circle at the anterior part of the head, above the mouth, raised above the surface, like warts, and prolonged as cylinders into the interior of the animal;" according to Professor Grant, containing a lens. Probably the sense of sight enjoyed by these creatures is of an order as low as its range is limited, but sufficient for them, "they creep, yet see."

The eyes of the centipedes resemble either those of the inferior classes already adverted to, or partake of the compound character of the insect-eye. In some, eyes have not been detected.

Insects, properly so called, possess two forms of eye, the simple and the compound, or aggregated. Some have the simple eye merely, others, as the butterfly, only the compound; generally, both kinds exist together in the same insect. The simple insect-eye may be described as a low form of that construction of which the human eye is a type, resembling

much the eyes of the spider tribe (Fig. XXIV. E), to be described hereafter. The compound eyes (Fig. XXV.) have ever excited the astonishment and admiration of observers, and are regarded as presenting one of the most magnificent and elaborate specimens of minute structure with which we are acquainted in creation. As, in the vegetable kingdom, the composite flower of the dandelion or hawkweed is constructed of an aggregation of simple florets, each, botanically speaking, in itself a perfect flower, so is the compound visual organ composed of an aggregation, greater or smaller, of simple eyes, each in itself capable of conveying the sensation of a certain limited portion of light, but, acting all together, conferring upon the creature an extensive field of vision. The surface of these eyes, examined under the microscope, is found to be divided into minute hexagonal spaces or facets (Fig. XXV. C). In the ant the divisions do not exceed fifty, but generally their number is much greater; in the dragon-fly they are computed to count nearly twelve thousand, and in butterflies greatly to exceed this almost inconceivable amount. Will has computed the facets on the eye of the

FIGURE XXV.



A, Eye of Cockchafer, enlarged section: 1, Ocelli; 2, Optic Nerve-Filaments; 3, Common Choroid; 4, General Retina; 5, Nervous Pillars proceeding from, 6, Enlarged Extremity of Optic Nerve. B, Single Ocellus, enlarged view: 1, Hexagonal Facet, or Cornea; 2, Lens; 3, Vitreous; 4, Retina Expansion of Nerve-Filament; 5, Choroid Pigment. C, Anterior view of Facets.

common house fly at four thousand nine hundred.

Every facet, or cornea, is "found to belong to a distinct eye, provided with a perfect nervous apparatus, and exhibiting its peculiar lens, iris, and pupil." The nature of the compound organ is most usually exhibited in the well-known figure of the magnified section of the eye of the common cockchafer (Fig. XXV. A). In this, from the bulbous extremity of the optic nerve, 6, there project a number of short nervous pillars, 5, which again unite to form a nervous expansion, 4, or general retina, which in this insect is covered by a bright red pigment, or choroid, 3. From this general retina numerous nervous filaments, one for each cornea or facet, pass through the common choroid, or pigment, each to supply its separate ocellus, 2, 1.

According to recent description, each separate eye (Fig. XXV. B) is composed of an hexagonal cornea, 1, covering a crystalline lens, 2, behind which is a vitreous humour, 3, and hyaloid surrounded by the retina expansion of the nerve-filament, 4, and this again backed by its layer of coloured pigment, 5, which rises between the conical ocelli to the

surface of the eye. In some insects, it covers a portion of the rim of each cornea, so as to leave merely a minute pupil for the transmission of light. Although the principle on which the compound eyes of insects are constructed remains the same, the details are of course liable to variation, and the proportions to be altered; the choroid, moreover, differs much in hue, and may be black, violet, blue, purple, yellow, brown, green. Minute hairs are, as in the bee, frequently observable between the facets, and the divisions are described as at times being projected like the cell-walls of a honeycomb.

Of the kind of sight which the insect derives through these compound eyes it is impossible to speak with certainty; it has been supposed that all objects within the range of vision at the same moment might be aggregated into one definite image, apparently continuous, but actually made up of numerous discrete portions, like a mosaic picture; more probably the creature has the power of directing attention through one ocellus at a time, which thus corresponds to the small central cone of rays, by which the defined but limited image of one object is formed in the refracting eye of

man, the rest of the picture being indistinct. If so, it is easy to see that this multiplication of minute eyes in the insect, and their aggregation into a fixed mass of more or less spherical form, is a beautiful compensation for the want of that power of movement which is conferred upon the eyes of the higher animal. The latter has the power of so turning and directing the organ, as to throw the image it wishes to view into the line of the centre of vision; the former has the organ so disposed and constructed, that, though fixed, it may collect at the same time distinct pencils of rays, each corresponding to this visual centre, from all surrounding objects, and in all probability has the power of giving the special attention of the moment to the impression conveyed by one ocellus only. Such we can easily conceive to be the case, from many of our own experiences as regards vision.

Lastly, it is very possible that these compound eyes are incapable of much adaptation to varied distance, and that, as Müller concludes, being fitted only for distant vision, the simple eyes have been provided for viewing near objects. The above high authority has cited many instances, to prove that the latter

are so placed as to be suited for this purpose only. However the fact may be, any one who has noted the rapid flight and instantaneous rectangular turns of a dragon-fly when feeding, must feel convinced that, in it, sight exists in perfection, quick, and well defined.

In the Arachnida, or spider tribes, the principle on which the eye is constructed much resembles those appertaining to the highest type. Professor Müller has shown in the eye of the scorpion (Fig. XXIV. E), which, from its size, admits of comparatively facile demonstration, that the cornea, the lens, the aqueous and vitreous humours, the retina, and choroid coat, are all in the same relative positions as in man, and that the sight of these creatures must be extremely perfect, more so, indeed, than that of any of the other articulated classes. The number of eyes in one individual varies from two to ten. Spiders, generally, have eight, arranged in two rows, on the back.

In crustaceous animals, of which the crab, lobster, and cray-fish are characteristic and best-known representatives, the eyes are either simple, agglomerated, or compound. The simple eyes, or stemmata, resemble those of the spider class just described, and never ex-

ceed three in number; the cornea, which is in immediate contact with the lens, being simply a modification of the common integument. The agglomerated organs consist of a number of simple eyes collected under one common cornea. The compound eyes resemble those of insects, and, like them, usually have hexagonal, but sometimes, as in the lobster, square facets, or cornea. A few species have a supplementary lens, inserted as it were in the cornea. Although the visual organs of insects are fixed and sessile, the immobility is compensated for, partly by the spherical form of the eye, partly by the mobility of the head itself. Crustaceous animals being deprived of the latter advantage, in consequence of the union of the head and thorax into one, in many of the higher genera, in which the habits and requirements call for more extended powers of sight, the eyes are placed upon the extremities of pedicles, or stems, which being jointed at their junction with the skull, are capable of movement in various directions, by means of the appropriate muscles attached to them. Some species are provided with a grooved cavity, or "orbit," into which they can draw the eye for protection (Fig. XXIV. F).

Evidently, the lower tribes of molluscous animals, such as the mussel, oyster, cockle, &c., fixed to one spot, or very slow in movement, do not require any visual organ at all, or one of much inferior powers and capabilities to that of the active Articulata. Accordingly, in many, eyes are not apparent, and where they do occur, are numerous, simple, and not confined to any one part of the body; forming, as it were, an "intermediate link between the diffused sensibility of the lower tribes and the localized eyes of the higher."

In the snail tribe the eyes assume a higher development (Fig. XXIV. D C), and resemble the simple eyes of insects and spiders, being, like those of the former, adapted apparently only for near vision. They appear like black spots, and are situated either at the extremity, middle, or base of the superior tentacula, or horns, as they are usually called (Fig. XXIV. C 1). The animal possessing the power of in-drawing or inverting these tentacula, along with the accompanying eye, and the optic nerve being long enough to reach the entire length of the organ when extended, provision is made for its being thrown into folds (Fig. XXIV. C 4) during the contrary state.

In the highest class of Mollusca, that to which belong the nautilus and cuttle-fish, the eyes contain all the essential parts of the organ of vision found in man, and in vertebrated animals generally, modified, of course, to suit the aqueous medium in which the creatures live and move. They are of comparatively large size, placed symmetrically on each side of the head, and sometimes on peduncles. The aqueous humour, nearly of equal density with the surrounding sea-water, is deficient, but the crystalline lens is of short focus and great power (Fig. XXXI. 1 1). It is described by Professor Jones as "having the form of a simple magnifier, most approved of by opticians as being best adapted to secure a large field of view."

Whoever is conversant with the principles on which the well-known "Coddington lens" is constructed, will have little difficulty in appreciating the advantages derived by introducing a precisely similar instrument in the eye of the cuttle-fish. The Coddington lens is a sphere of glass, divided into two portions by a deeply cut circular groove, which is filled up with opaque matter. The lens of the cuttle-fish is in like manner divided into two parts, of

unequal size, by a circular indentation, wherein the post-pigmental retina, with its coat of dark varnish, is fixed, and thus a picture of the most perfect character is ensured. Another striking peculiarity connected with the eye of the cuttle-fish is the absence of a proper cornea, there being merely a transparent covering continued from the proper integument of the front of the orbit (Fig. XXXI. 2), on raising which, the lens is found naked and exposed beneath (Fig. XXXI. 1). One step more brings us to the eye of the vertebrated fish, complete, as in man.

CHAPTER VIII.

Comparative Anatomy of Eye.

EYES GENERALLY — FISHES — ADAPTATION TO WATERY MEDIUM—FLAT FORM—-SPHERICAL LENS — CARTILAGINOUS PLATES — PLAITED NERVE — AMPHIBIA — REPTILES — BIRDS — ADAPTATION OF FORM OF EYE — OSSEOUS PLATES — PECTEN — ADAPTATION IN RAPID MOTION — OWLS — AQUATIC BIRDS — EYELIDS AND MUSCLES — MAMMALIA — EYES GENERALLY—WHALE TRIBE—AMPHIBIOUS MAMMALIA — MOLE —ORBITS—PUPILS—TAPETUM LUCIDUM.

CHAPTER VIII.

COMPARATIVE ANATOMY OF EYE. VERTEBRATE ANIMALS—FISHES.

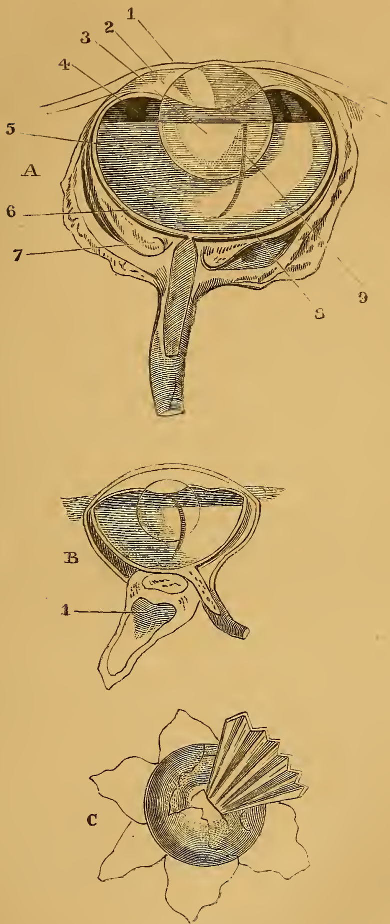
In the nautilus and cuttle-fish, we find the representatives at once of the uppermost grade of molluscous animals and of the most highly organized class, the most largely brain-endowed of the lowest of the two great divisions of the Animal Kingdom, the Invertebrata. Did the object of the present essay lead to the inquiry, these beings would be found to possess general structure and special senses, so highly developed as to make the step but a short one to the lowest class of the Vertebrata, that higher division of animated beings, characterized by the possession of an internal skeleton, more or less osseous, or bony; of a brain-mass collected into and defended by a hard bony case; and of structures, senses, and capabilities very greatly exceeding those of the inferior division.

The eyes of vertebrated animals, two in number, and disposed symmetrically on each side of the head, are constructed precisely on the same principle, and with the same parts similarly disposed, to those of man himself. Behind a transparent cornea, an aqueous fluid more or less in quantity, floats the iris, and covers the crystal lens, behind which a vitreous body, inclosed in a hyaloid, and surrounded by a nervous retina, a coloured or lustrous choroid, and a fibrous, cartilaginous, or bony sclerotic, completes the visual instrument.

How the principle of construction is modified, by alteration of form or by apt addition, and yet, in conformity to the great laws of light, is made subservient to the every-day requirement of the class, it will be the object of the present chapter to explain.

In fishes, which constitute the lowest class of vertebrated animals, the eyes, though constructed after the human type, are found to present modifications adapting them for the fulfilment of their office, in the dense medium in which the creatures live and move. A reference to Fig. XXVI., A B, will show that a comparatively flat cornea covers a spherical crystal lens, and that the capacity of the aque-

FIGURE XXVI.—EYES OF FISH.



A, Enlarged Section: 1, Cornea; 2, Aqueous Chamber; 3, Lens; 4, Iris; 5, Vitreous; 6, Retina; 7, Sclerotic Coat, with imbedded plates of cartilage; 8, Choroid; 9, Falciform Process. B, Section of Eye on a peduncle, 1. C, Posterior View of Fish Eye, showing position of muscles, and optic nerve opened out to show its plaited structure.

ous chamber is extremely limited, containing just sufficient fluid to float the iris; further, that instead of the spherical form of the human eye, the organ in the fish is diminished or flattened in its antero-posterior diameter, that is, from before backward, so as to throw the posterior surface of the lens very near the retina. The slightest reflection in connection with optical laws must at once show how admirably these modifications in the form of the fish eye are adapted to meet the altered conditions consequent upon the density of the medium through which rays of light are conducted to it, and to give clear vision, which could not possibly have resulted from eyes constructed after the same proportion as those of air-breathing animals.

An aqueous fluid, of density scarcely differing from that of the surrounding water, could have but little effect in refracting rays of light towards a sight focus; accordingly, we find a dense lens brought close up to the flattened cornea, a lens, too, of which the form gives such a degree of refracting power as may compensate for the dense nature of the medium through which the rays are received. The focus of this spherical refractor being necessarily very short, the alteration in the shape of

the eye conforms the position of the receptive retina to the diminished focal distance, by bringing it relatively nearer to the lens than it is in terrestrial animals. The flattened form of the eye of the fish, which is the necessary result of these modifications, is preserved by additional firmness imparted to its sclerotic coat, most frequently by two strong plates of cartilage (Fig. XXVI. A 7 7) imbedded in its substance, at times by the cartilaginous hardness of the entire tunic itself, or by its conversion, in some of the larger fishes, into a complete cup of bone.

The iris in the fish (Fig. XXVI. A 4), usually bright coloured externally, dark, like the choroid, within, and surrounding a pupil of wide circumference, for the admission of much light, is possessed of little, if any, of that mobility and power of contraction requisite for the visual perfections of beings subject to the varied intensities of atmospheric luminosity. In some fish, its upper edge is continued over the pupil, in the form of a palmated or vine leaf-shaped process.

Visual adaptation is most probably effected by a vascular organ of a deep red colour, the choroid gland, situated between the coats of

the choroid membrane, and which, by its distension or relaxation, probably confers upon fish the power of adapting the eye to varied distance. That fish do possess such a power, and in considerable perfection, is evident from the fact familiar to every one who has handled a fly-rod, that a fish will rise with great rapidity from a considerable depth, and accurately seize, or sagaciously refuse, the artificial insect. Besides the choroid gland, the eyes of fishes present another addition not found in other animals, in the form of a delicate sickle-shaped projection from the retina—according to some, from the choroid gland—which passes in the vitreous humour along the cavity of the globe, and is fixed to the capsule of the lens (Fig. XXVI. A 9). Its object is probably to maintain the refracting media of the eye *in situ*, and its necessity, perhaps, arises from the nature and pressure of the surrounding medium.

To the eyes of fish, constantly exposed to the action of water, lachrymal apparatus would evidently be a superfluity; it is consequently absent, and, doubtless for the same reason, eyelids are unprovided. The eyeballs, although comparatively little moveable, are, like those of man, provided with six muscles, four straight

and two oblique; neither of the latter, however, arise from the back of the cavity, as in the human orbit, both are situated entirely in front. In some fishes, as in the sharks and rays, the eyes are supported on moveable cartilaginous pedicles (Fig. XXVI. B 1), articulated to the bottom of the orbit, and allowing of greater extent of motion; their position in the head, moreover, is different in different species; "in some they are placed high up near the top, more frequently on the flattened side of the head, but always so situated as best to suit the exigencies of the particular fish." In fishes which bore in sand or mud, the eyes are comparatively smaller than in other species; and in the eel they are covered by a dense transparent membrane, continuous with, and separating along with, the general integument.

Although the inner layer of the choroid is generally dark, in some fishes it possesses the brilliant metallic lustre observed in species of land animals; externally it has a beautiful pearly, shining appearance. The composition of the lens, of transparent, serrated fibres (Fig. XXII.) has already been alluded to in the description of that of man. The structure of the

optic nerve in many fishes is peculiar and beautiful. When its investing membrane is removed, the nerve tissue is found to be disposed in plaitings, which, opened out, closely resemble a fan (Fig. XXVI.) The exact object of this arrangement is unknown; but doubtless it is requisite for the perfection of the visual organs, with which He who created them all in wisdom has endowed and fitted the "tenants of the deep," to make their way through the "paths" of the great waters, fitted them in myriads for the enjoyment of the gift of life, of existence in their own peculiar element—in that "great and wide sea wherein are things creeping innumerable, both small and great beasts," and who, when He had created, saw that all was "good, and blessed them," saying—

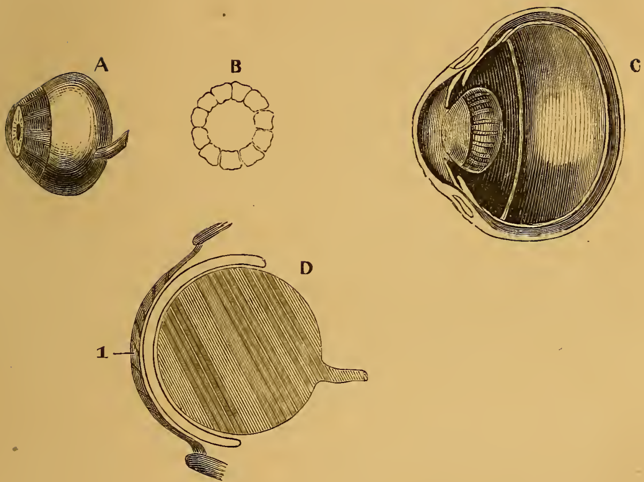
"Be fruitful, multiply, and in the seas
And lakes and running streams the waters fill.
. . . . Each creek and bay
With fry innumerable swarm, and shoals
Of fish, that with their fins and shining scales
Glide under the green wave,
. . . Or, sporting with quick glance,
Show to the sun their waved coats dropt with gold."

AMPHIBIA AND REPTILES.

In amphibia, of which the frog is the most familiar example, the eyes, as we might perhaps expect, hold a place somewhat intermediate between the same organs in fish and those of air-breathing animals in general—the cornea remaining flat, the aqueous deficient, the lens more or less spherical, the iris nearly without motion, and, undoubtedly for the same reason as in fish, no lachrymal apparatus provided. On the other hand, not only are upper and lower eyelids developed, but, as in birds, the third or nictitating membrane.

In those reptiles, as serpents, lizards, &c., which exist entirely on land, the eyes approach more nearly the optical proportions displayed in those of man and of the higher animals, the cornea becoming more convex (Fig. XXVII.), the aqueous more abundant, and the lens less spherical; at the same time, considerable variation is observed in the arrangement of external appendages, and in some species, as the tortoise, turtle, &c., the sclerotic coat of the eye is surrounded anteriorly by a circle (Fig. XXVII., B) of bony plates, as in birds. The motor apparatus, of four straight and two

Figure XXVII.—Eye of Reptiles.



A, Eye of Tortoise. B, Osseous Plates of Eye of Tortoise. C, Enlarged Section of the same Eye. D, Diagram of Eye of Serpent, showing: 1, The Continuation of the common Integument over the Cornea.

oblique muscles, is similar to that of the fish; lachrymal organs are developed, there exists a nictitating membrane, and upper and lower eyelids are more or less moveable; the latter are sometimes united, and extend over the eye, being either pierced merely by a fissure for the admission of light, as in the chameleon, or, as in serpents, forming over the cornea a perfectly continuous transparent covering (Fig. XXVII., D), which is merely a prolongation of the common integument, and is regularly exuviated, or cast off, with it. The lachrymal fluid is described as flowing beneath this outer covering of the eye, and being, as in man, carried off by a lachrymal duct.

BIRDS.

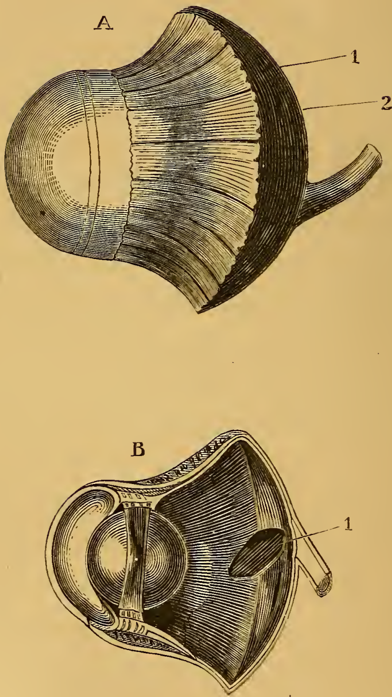
In our inquiries hitherto, amid the comparatively low grades of creation, the visual organs have been found exactly suited to the position, the habits, and requirements of the creature, neither exceeding nor falling short. With such premises any reflecting mind, reasoning from the known habits and varied endowments of birds, would expect to find in them vision, regarded as vision merely, in its most perfect state and most capable adaptation; and

such it is, suited alike to the swift darting turns of the swallow, to the rapid swoop of the hawk, or to the nocturnal predations of the owl—in each perfect.

The eyes of birds, generally, are comparatively of large size, commensurate with their importance to the well-being and existence of creatures to which they must be indispensable; we cannot conceive the possible existence of a class of blind birds, and none such has ever been discovered. Less moveable in their sockets than the eyes either of man or quadruped, the deficiency is compensated for by the greater prominence of the cornea, the lateral position of the organs, and the great mobility of head and neck.

The eye of the fish exhibits an organ proportioned in strict accordance with the laws of optics, to confer as perfect vision as possible upon creatures living and moving in a watery world; how opposite must be the structure of the same organ, fulfilling all the requirements of their life, to the dwellers in "the mid aerial sky," the far-seeing birds of the air? Exactly opposite. Instead of flat, the cornea is extremely convex, the axis of the eye from behind forward lengthened, the aqueous and vitreous

Figure XXVIII.—Eye of Owl.



A, External view: 1, Osseous plates. B, Section: 1 Marsupium or Pecten.

abundant, the lens comparatively flat, and its density diminished (Fig. XXVIII.)* In rapacious birds more especially, in which the tubular form of eye and rapid adjustment are specially called for, the former is preserved, and the sphericity, which the combined fluids of the eye would normally tend to give the organ, obviated by a circle of imbricated osseous plates (Fig. XXVIII., A 1) as in reptiles, enclosed between two layers of the outer sclerotic coat anteriorly, and extending as far as the margin of the cornea. These plates, obviously, must not only resist pressure of the fluids from within when the whole eyeball is pressed upon by its external muscles, but from their capability of overlapping, materially assist the rapid adjustment of the eye to distance, by throwing the whole weight of the pressed fluid to increase the convexity of the cornea. Of course, these plates do not extend so far in birds generally, as they are represented to do in the night-feeding, predatory owl. The contrary state to that

* In this figure, which represents the eye of an owl, the lens is spherical, belonging to a creature which exerts its sight in dim light. The same exceptional form occurs in the cormorant, and other birds which seek their prey in water by the eye.

alluded to above, flattening of the cornea, will of course result from muscular relaxation generally; but the muscular fibres of the ciliary body demonstrated by Sir P. Crampton, must undoubtedly assist materially the adjustments of the eye, drawing back the cornea by their attachment to its internal layer.

The iris in birds is frequently bright coloured. It is susceptible of much movement, and, more particularly in night-feeding birds, is capable of affording great breadth of pupil. In some classes, moreover, as in the parrots, its movements appear subject to the voluntary control of the individual.

The choroid coat of the eye in birds is, like the human, covered with dark pigment, and forms, anteriorly, ciliary folds or processes.

The optic nerve, instead of piercing the eye of the bird like a round cord, as in man, becomes flattened out vertically; it still, however, contains in its substance arterial vessels, which pass through the slit formed in the retina by the entrance of the nerve, and are devoted to form one of the most remarkable means of optical adjustment met with in organs of vision—the marsupium, or pecten, a body composed of folds of vascular membrane, and

supplied by these central arterial branches which enter in the substance of the nerve. This vascular organ (Fig. XXVIII., B 1), which varies much in the number of folds composing it, is inserted, or wedged, into the substance of the vitreous humour, passing forward to a greater or less extent, in some birds even as far as the lens. It is covered with the black pigment of the choroid, but is quite unconnected with the tunic itself. Whatever other uses this remarkable addition to the ordinary structures of the eye may subserve, its evident capability of being distended by additional blood poured into it—as in similar textures—or of being relaxed, points it out as admirably adapted for the office most generally assigned to it, that of assisting the optical adjustment of the eye; either by, in its state of distension, pushing forward the lens, and convexing the cornea for near vision, or, in its relaxed condition, allowing the textures to fall back to their usual state by their own natural resiliency. Thus we can imagine the bird of prey "loosely wing" the air, and scan, calmly but attentively, the far-beneath, the eye comparatively at rest, and adapted, by its lessened convexity, to distant vision; suddenly the looked-for victim is

seen, passion is aroused, and as with lightning-like swoop the bird descends on his prey, the blood of excitement pressing the distensible organ of the pecten, adapts the eye more and more to the rapidly-diminished distance, and by thus enabling the object seen from high in the air to be kept in view through the long, but fast descent, makes even the nimble-moving mouse an easy prey.

In addition, however, to this great power of sudden adjustment which must necessarily be possessed by predacious birds, the class generally have a keenness and length of sight superior to that of any other division of the animal kingdom. Buffon states that a hawk can distinguish a lark on the ground, of a similar colour to the clod of earth it sits upon, at twenty times the distance a man can. Unquestionably this power must be greatly owing to increased nervous sensibility of the special sense; it is, however, assisted in many species of rapacious birds, in consequence of the eye being screened from light by superciliary ridges of feathers, so that the organ is enabled to be concentrated without distraction upon things beneath.

An arrangement somewhat analogous is said

to be found in the male glow-worm, by which he is enabled, while winging his flight in the air, better to descry his creeping mate on the ground. The quick perceptive sight of the swallow, and of other birds which make rapid, short darts and turns, affords yet another instance of the remarkable sensibility and quick accurate adjustment of sight in this class of created beings.

In birds of prey, again, which feed by night, more especially the owls, the eyes, in addition to being very large, with a large pupil, are surrounded by a disk of shining white feathers, which answer the purposes of collecting and reflecting all available light which can assist vision; this "facial disk," however, is but feebly developed in owls, which hunt by day.* In contradistinction to the large eyes of the night-feeders, humming-birds, which seek their food under the mid-day glare of a tropical sun, have eyes, actually and comparatively, most minute.

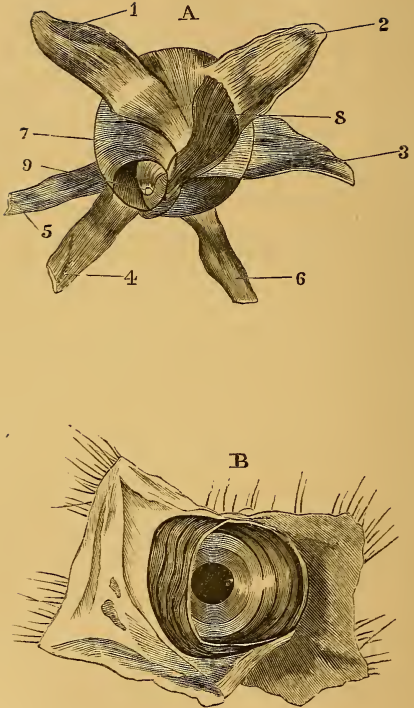
In such aquatic birds as ducks, finding their food under water, rather by the sensibility of the beak than by sight, the eyes are comparatively small in size, and of flattened curve.

* Swainson.

Probably the most remarkable adduced instance of the perfection of sight in the feathered tribes, is that of the condor of South America. It has been fully proved* that this carniverous bird cannot discover carrion by the sense of smell alone, even when very close to it; it is not likely, therefore, to do so at the immense distances from which condors discover the dead body of an animal; to the sense of sight, therefore, has been attributed the faculty they possess, but so incredible does it seem, that naturalists have endeavoured in other ways to account for the phenomenon. There yet, perhaps, remains to be discovered a sense, an instinct which guides the creatures of instinct in their far journeyings—the dog to the home of its master, over trackless hills or across rapid rivers—the "birds of the wandering wing" "through the wastes of the trackless air." Sight may not do all this, and though we cannot, as in the case of a special sense, lay our finger upon it and say here lies the instrument, there is every good reason to attribute the wonderful faculty, thus displayed, to some special instinct with which the Almighty has gifted these, His lower creatures, by which He

* Darwin's "Voyage of a Naturalist."

Figure XXIX.



A, Muscles of Eye of Bird: 1, 2, 3, 4, Straight or Recti Muscles; 5, 6, Oblique Muscles; 7, 8, Muscles of Nictitating Membrane winding round; 9, Optic Nerve. B, Bird's Eye, eyelids turned back to show: 1, Nictitating Membrane.

guides the "ranged figure" of the "a'ery caravan high over seas," till, "desert and deep" passed over, "each worn wing hath regained its home."

The eyes of birds are protected by upper and lower eyelids, and by a third or nictitating membrane. The lower eyelid differs from that of man in being the more moveable and extensive, and by the possession of a depressor muscle, similar in action to that described as elevating the upper human lid. Eyelashes are present in some species, more particularly in such as seek food among close thickets or dense foliage they are thick and strong. A lachrymal gland and apparatus exist, and another gland, situated underneath the conjunctiva, at the inner angle, supplies a lubricating fluid.

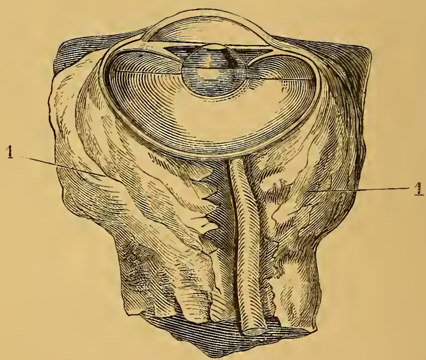
The third eyelid, or nictitating membrane (Fig. XXIX., B 1), is sometimes sufficiently transparent for the bird to look through it when drawn down; more generally, however, it is drawn, with a momentary sweeping motion, rapidly over the surface of the eye, by a strikingly beautiful arrangement of muscular mechanism. In addition to the four straight and two oblique muscles of the eyeball (Fig. XXIX.,

A, 1, 2, 3, 4, 5, 6) in the bird, two other muscles (7, 8) are provided. The square-shaped muscle (8), arising from the upper and anterior part of the globe, descends backwards towards the optic nerve (9), where its fibres form a long pulley or sheath, through which passes the tendon of the second muscle (7), as it winds round the optic nerve before passing through a fibrous sheath under the eyeball, to be attached to the lower angle of the membrana nictitans. A moment's reflection will at once make plain how the simultaneous action of these two muscles is exquisitely adapted to fulfil the object of their construction.

MAMMALIA—QUADRUPEDS.

Our inquiries have at length conducted us to the highest class of vertebrated animals—the loftiest reach of the scale of animated nature—the Mammalia, which, deriving their name from the characteristic provision for the nourishment of their offspring, by virtue of the endowment, extend to man himself, the last link of the great chain of physical nature, and in the love of that offspring exhibit the nearest approach which "the brutes that perish" make to

Figure XXX.



Section of Eye of Whale, showing—1, greatly thickened Sclerotic Coat.

man, who has life and immortality before him. The "masterwork"—

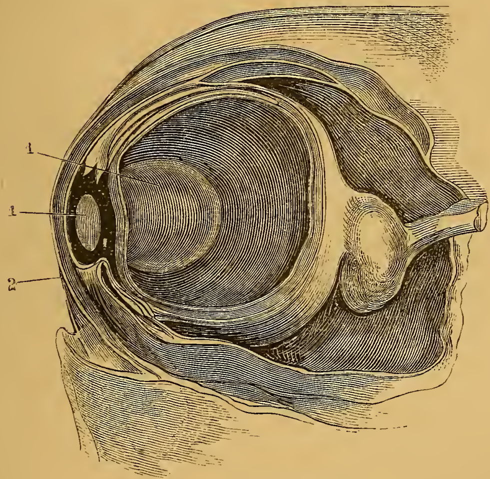
> "Who not prone
> And brute as other creatures, but endued
> With sanctity of reason, might erect
> His stature, and upright, with front serene
> Govern the rest."

In mammalia generally, living in the same medium, with habits and requirements approximating those of man, the proportional arrangements of the eyes do not differ essentially from those of the human organ, the description of which—already given—is sufficiently applicable to the class at large to render any repetition superfluous. At the same time, there are found among the lower animals certain modifications by which the eye is adapted to the peculiar necessities of the creature, too striking not to be adverted to. The greater proportion of the mammalia are quadruped animals, living constantly on the surface of the land; but there are classes belonging to the order whose life is essentially different, the most remarkable, perhaps, being the warm-blooded whale tribe, inhabiting the depths of the ocean, which, amid other modifications, have the spherical lens and flattened form of the fishes' eye (Fig. XXX.)

The eye of the whale, indeed, appears nearly spherical externally; but this appearance is caused by the extreme thickness—at least one inch—of the cartilaginous sclerotic (Fig. XXX., 1), which encloses the compressed globe, and is, doubtless, required to preserve the form of the organ under the immense pressure to which it must be subject in deep water. In whales, as in fish, lachrymal organs are absent, although eyelids, and a gland for the secretion of lubricating matter, exist; moreover, the tribe resemble fish, but differ from other mammalia in having both the oblique muscles of the eye arising from the fore part of the orbit.

As some mammal animals are amphibious in their habits, living generally in or under water, but visiting land occasionally, the eyes of course require the power of adaptation to the varied circumstance. This is well seen in the Greenland seal, described by Blumenbach as having the cornea thin and yielding, the anterior segment of the sclerotic thick and firm, its middle circle thin and flexible, and, again, the posterior segment thick, almost cartilaginous, the whole eyeball being surrounded by strong muscles, capable either of shortening, or

Figure XXXI.—Section of the Eye of the Cuttle-fish.



permitting the elongation of the visual axis, according to external requirement.

In burrowing animals, as in the mole, the orbit is very superficial, and the extremely small eye protected from injury by a covering of fur.

The bony orbits, so deeply capacious in man, exist in less proportion in mammalia generally, and the relative axes, both of orbit and eye, differ much in different species, being more frequently directed outwards, so as to afford a considerable extent of lateral, and, when very prominent, as in the hare, even of posterior vision. In nocturnal-hunting quadrupeds, and in man, the eyes being directed forward, and their axes parallel, or nearly so, a greater precision of sight is thereby attained.

All the land-dwelling mammalia have the superior oblique muscle, as in man, passing through a pulley; a few possess a gland similar to that in birds, at the inner corner of the eye, for the secretion of lubricating fluid.

In a few animals the form of the pupil varies from round; in the cat tribe the opening is vertical, and its enlargement and contraction appear to be under the voluntary control of the animal, the arrangement being doubtless con-

nected with its peculiar night-hunting habits. In many of the mammalia the posterior portion of the choroid is deprived of pigment cells, and instead possesses a shining, metallic lustrous surface, the tapetum lucidum, which, instead of absorbing, reflects the smallest portions of light that may enter the eye. The well-known glare from the eye of the cat is caused by the reflection of rays of light from the tapetum lucidum; other animals exhibit the same phenomenon. It may be observed that this reflection cannot happen—is not developed—in absolute darkness, but requires some amount of light; very little, however, suffices.

In our investigations of the general anatomy and microscopic structure of the human eye, how admirable did all appear—how far transcending, beyond hope of approach, the highest productions of human art. In our further investigation of the physiological fulfilments of the same organ, how exact the keeping, how exquisite the adaptation to the one great end, causing the most perfect human instrument to sink into insignificance in the comparison. From the contemplation of this high type of optical arrangement, we descended at once to the lowest manifestations of a visual organ, the simple

ocellus, or eye-dot, of the humbler classes of animated nature, thence ascending, and having passed in brief review the modifications of the organ in the various classes of the animal kingdom, we have arrived at that stage where the next step is once more to man himself. How many different forms of animated existence are comprised within the vast limits of that one division of creation, the animal kingdom—how all but infinite in variety the habits, requirements, and conditional existences of its component creatures; and yet, in all and each, every structure is perfect. In the one we have found it so; in the creeping things of earth—in the tenants of the mighty deep—in the birds of the air—in beast, in man, the eye is the work of God.

CHAPTER IX.

On the Wisdom of God

DISPLAYED IN THE STRUCTURE OF THE EYE.

CHAPTER IX.

THE WISDOM OF GOD AS DISPLAYED IN THE STRUCTURE OF THE EYE.

"A SINGLE example seems altogether as conclusive as a thousand; and he that cannot discover any trace of contrivance in the formation of an eye will probably retain his atheism at the end of a whole system of physiology."*

To the man who, in contemplating the works of creation around him, whether the "curiously wrought" structures that tax the highest powers of the microscope to unfold their beauty, or the wide expanse of the "universal frame," so "wondrous fair," which the most far-searching glass of the astronomer cannot fathom—to him, knowing, feeling the irrepressible conviction that all is the work of an Almighty hand, nothing is more puzzling than the state of mind which requires to argue

* *Edinburgh Review,* vol. i., p. 289.

itself into the belief of the existence of one omnipotent and all-wise Author of all, nothing more fearful than that wilful blindness which closes the eye of a fool who says "there is no God," and who, wrapping himself up in the pride of his own fancied intelligence, seeks only for what he imagines flaws and errors in the grand cosmorama, gives ear only that he may catch some jarring note in the "music of the harp of universal nature," and, led by his own imperfect or disordered impressions, mistakes for discord the variation which he cannot understand. For such a state of mind it is useless to multiply instances; structure, arrangement, adaptation, may be presented to the eye of that rational mind which in this world man holds by the free gift of the God who made him, but into that higher region of his spiritual being—that lofty, real intelligence which raises him above the brutes, and fits him for immortality—that inward temple where the things of God and heaven meet those of earth, the "wonderful works" of creation carry no conviction; the door is shut by the free agency of that will which overrules the understanding; the whole being is compassed about with the fitful sparks and fancied shining of the fire itself hath

kindled, and knows not that it "walketh in darkness and hath no light." Gladly we turn to the mind that thinks it no degradation to acknowledge that all is from God—that the ever-flowing life from Him sustains all in perfection and harmonious working, even the power of man's physical and mental being; to the mind which, exploring the deep arcana of Nature, accepts her great book as a second revelation—the scripture of material creation—the mighty tablet on which the hand of Omnipotence has written in the effects of wisdom the ends of love.

The greatest intellects have ever been the most humble, and "those who have been discoverers in science have generally had minds the disposition of which was to believe in an intelligent Maker of the Universe."* It is matter of familiar history that Newton, at the close of a life devoted, all know how successfully, to the elucidation of truth, compared himself to a child who had been playing on the shores of a mighty sea, picking up here and there a beautiful shell or shining pebble, but with the great ocean of truth still unexplored before him, so well did he feel the inadequate

* Whewell, "Indications of the Creator."

power of the human mind—and that mind a Newton's—to search the infinite things of the truth of God.

What says a philosopher,* who has been among the foremost to travel and push forward the path cleared by the great author of "The Principia ?" "The further man inquires, and the wider his sphere of observation extends," instances of unlimited power and intelligence "continually open upon him in increasing abundance;" "the study of one prepares him to understand and appreciate another, refinement follows on refinement, wonder on wonder, till his faculties become bewildered in admiration, and his intellect falls back on itself in utter hopelessness of arriving at an end."

"Try," said Galen, the anatomist, "if you can imagine a shoe made with half the skill which appears in the skin of the foot." How forcibly does this tell of the opinion of one intimately acquainted with the fearful and wonderful structure of the human frame, who had all the still more striking manifestations of design and wisdom to refer to; and if in the skin of the foot, how much more in that high organ of special sense treated of in these pages,

* Herschel's "Discourse on Natural Philosophy."

of which an already quoted philosopher has said—"It is the boast of science to have been able to trace so far the refined contrivances of this admirable organ, not its shame to find something still concealed from its scrutiny; for, however anatomists may differ on points of structure, or physiologists dispute on modes of action, there is that of what we do understand in the formation of the eye so similar, and yet so infinitely superior to a product of ingenuity—such thought, such care, such refinement, such advantage taken of the properties of natural agents used as mere instruments for accomplishing a given end, as force upon us a conviction of deliberate choice and premeditated design more strongly, perhaps, than any single contrivance to be found, whether in art or nature, and render its study an object of the deepest interest."*

If the examination of any portion of the corporeal frame of man or animal, either in connection with its general anatomy, its microscopic structure, or its animated physiology, affords such proof of all that is wise and good, as fails not to excite wonder in the dullest mind, or to command the admiration of all

* Sir John Herschel.

intellects not wilfully blinded against the truth, it needs not again to recapitulate detail, or again to direct attention to the exemplification of great wisdom in the individualities of the varied structures of the eye; man's words can add nothing to the stereotype of their evidence that they are the work of an all-wise and all-powerful Being—of a God, and we know but one.

The greatest natural historian of the present age, the venerable Humboldt, describes nature as "a harmony blending together all created things, however dissimilar in form or attributes, one great whole (τὸ πάν) animated by the breath of life:"* a living world which, like its great Author, neither slumbers nor sleeps, every particle tending to some end—nothing wasted, nothing lost, all in movement, yet in order. How certain, then, that what appears to us one of the highest elaborations of Divine workmanship in material things, the organ of vision, must be in harmony with itself in all its parts, in harmony with the laws which regulate all material things, in harmony either with the physical wants of the lowest creature, or with the requirements of the God-like mental

* "Cosmos."

attributes of man. The one instrument ruled by the same laws, constructed upon the same general principles, modified to suit the need, not of classes and orders merely, but of the unnumbered individual species which constitute the great sum of animated nature. And yet men—nay, philosophers—have the hardihood to impugn the harmony of this mighty whole. And why? Because, forsooth, they have here and there met with something which *appeared* out of place, useless, which did not accord with *their* ideas of what ought to be. Witness the case of the aspalax, a burrowing animal, which, "from its living underground, is said gradually to acquire blindness in its subterranean abode," and which has eagerly been quoted by Lamarck as a proof of the want of unity of design and of development guided by circumstances. Alas! for the human mind when blinded by its own prejudices. Might not the view of that vast edifice of symmetry, before which the greatest minds of Christian or even of heathen philosophy, though but "darkly wise," have fallen back in awe, suggest to the sceptic that the apparent inconsistency arose from some little deficiency in the extent of his own knowledge, some little fact undiscovered

or unthought of, and induce him to exchange his captious sneer, and dreary contemplations, for the happier faith of those who look with "reverent thought and eye to heaven," who lay their own attainments at the foot of his throne, whom they acknowledge as the "one only Guide of all agents natural, and both the Creator and Worker of all in all, alone to be blessed, adored, and honoured by all for ever?"

CHAPTER X.

The Philosophy of Vision,

AS ILLUSTRATIVE OF THE BENEFICENCE OF GOD.

CHAPTER X.

THE PHILOSOPHY OF VISION AS ILLUSTRATIVE OF THE BENEFICENCE OF GOD.

THE sceptical critic of God's works may seek till he finds fancied flaws, or chisel-marks unsmoothed upon the grand structure of the universe, but he cannot, without stultifying himself, escape the acknowledgment of the beauty of the edifice, whether in its sublime simplicity or in its elaborate detail. He knows he cannot thoroughly explore, much less fashion, one component element of the mighty whole, but yet he must form, after his own imagining, the cause of so glorious an effect. He calls it "nature," "progressive development," "necessary law," and sets up, in the place of the great Author of all things, the something—the nothing—*ignis fatuus* of his own fancy. A cause he knows he must have, but—here lies the offence—that cause must not be a being greater

than himself, one to whom he must render the homage of moral and religious obligation; and thus the physical law is substituted for the spiritual being. He who thus regards the source of the great wonders of creation may, it is true, find in their study the excitement of deep intellectual interest; but as long as he sees merely the cold effects of certain causes, and regards not the beneficence, that end written upon all his works by the great First Cause—his heart, himself a stranger to the warming influences of that love which his mind repudiates, its vivifying beams excluded from his own little mental world—to him, instead of the bright tints and cheerful hues of summer warmth, the aspect is that of winter: the light may be clear, but all is cold and dead.

Hitherto the intellect, chiefly, has been appealed to; now the heart is asked for, that we may rightly not only see, but feel that God, although

> "To us invisible, or dimly seen
> In these his lowest works; yet these declare
> His goodness beyond thought and power divine."

In the lower animals the sense of sight, ever in exact accordance with the habits and requirements of the creature, must necessarily

be a blessing in the same proportion that existence itself is so—the perfection of the senses and the perfection of their life must be inseparable; they live in those senses, at once their instinctive guides and constant rulers, linked in one harmonious whole with the mental constitution and physical organization of the being. It is evident, therefore, that the gift from God in the bestowal of the eye of the individual animal—whatever the nature of that eye—is in exact proportion to the gift of existence itself.

It is difficult, probably insuperably so, to separate by anything like a defined boundary the obviously instinctive from the apparent reasoning powers of even the higher animals; consequently, in the consideration of acts evidently resulting from impressions derived through the sense of sight, it is impossible to do more than conjecture how far any mental process, approaching what we name and feel as reason, is concerned—how far it is simply instinctive, how far what we might call pleasurably instinctive.

The lower the grade of animated existence examined, the greater the difficulty. In the attraction of insects by light—of fish by light, gaudy colours, or glittering objects, we see the

first dawnings of what may be classed as pleasurable impressions and instinctive acts, resulting from the exercise of the sense of sight.

In birds the manifestation is higher, though the difficulty of definition is the same; nevertheless, in the affectionate regard with which many species attend to their young, in their attachments displayed either to each other or to man, the act of seeing must necessarily be an adjunct, at least, to the other pleasurable emotions experienced. We find, too, as in fish or insects, the same attraction exerted upon various species of birds by bright colours and glittering objects. How far the thieving propensities of the magpie, for instance, are connected with the gratification of the sense in question, it is impossible to say; we see, however, the same propensity for collecting still further carried out, and applied solely to the purpose of ornamenting their singular constructions by the curious "bower birds" of Australia, which seem to derive so much pleasure from picking up all stray articles, more especially of bright colour or glitter, for the use and arrangement of which we can assign no other purpose than the gratification of their sense of sight.

In the mammalia—more especially in the higher quadrupeds—the look of affection frequently bestowed upon their young speaks plainly of the pleasure the sight conveys—truly of the sight, in superaddition to the mere sensation of having them near them; for never is the young more affectionately regarded than when in the act of drawing nourishment from the mother. The effects of bright colours, particularly of scarlet, upon many animals is well known, more especially in connection with their antipathies; mental impression, therefore, of a decided kind is evident, but to what extent pleasurable, or the reverse, we have no means of judging. Its power has recently been illustrated by some curious observations,* which tend to show that the colours of the buildings by which domestic animals are habitually surrounded, or even the hues of more transient objects, exert considerable power over the colours of the young produced by the animals subjected to the influence.

Lastly, in the attachments of animals, either to each other or to man, we have exhibited another pleasurable association, springing, in part at least, from visual perception. If it is

* *Monthly Journal of Medical Science*, November, 1850.

impossible for us to realize, in our own minds, the nature of the mental impressions of the lower animals, this, nevertheless, we do know, that they are endowed with organs of vision exactly adapted, as far as we can judge, to the conditions of their sensual existence—an existence evidently happy, but being dependent for that happiness upon sensual perfection, seldom, as a general rule, prolonged when a sense like vision fails, or is destroyed. Except under the kind care of man, in the case of domestic animals, partaking with him of the advantages of his civilization, we cannot conceive those creatures of sense existing long without sight; and indeed it seems as if the instinctive propensity, of wild animals especially, to attack and kill any of their own species which have become blind or disabled is a merciful provision against continued suffering, when the capacity for enjoyment has been lost. We do, indeed, hear of a few instances in which, as among rats, one blind from age has been guided and cared for by the others; but such cases are rare, and truly exceptional.

MAN.

As a matter of course, the lower man's position in the social scale, the more nearly he approaches the condition and habits of the lower animals; in the same degree does his exercise of the sense of vision, and the results derived therefrom, descend to the sensual animal level. In the savage, it guards him from enemies and danger, assists him to procure food, and associates the forms of those by whom he is surrounded, more particularly of offspring, with his mental affection; but from his eye he derives simple perception, or little more. It may, it is true, be educated to rival, in some measure, the piercing ken of the bird of prey, to distinguish the trail invisible to the eye of civilization; but these are perceptions little, if at all, higher than animal possessions, and unconnected with the more elevated and God-like powers of the mind: the one is of the "earth, earthy," the other reaches unto heaven. But yet, in one important particular, man's vision, even in his rudest state, differs from that of the brute — it requires education. Whatever practical application it is capable of,

is the result of experience; the lower animal is born into its full knowledge and power in this respect. The infant in the cradle grasps at the suspended object, although a foot or two distant; the chick, just emerging from the shell, picks up the particle of food, or seizes the insect with as much accuracy as its parent; but as it is born, so it dies—it ascends no higher. In the human infant, the first attraction of the wandering sight by indifferent objects, or by some article connected with its food, is quickly succeeded by the fixed gaze on its mother's face, and recognition of its mother's smile; asserting thus early its claim to the blessed privileges and high destinies of humanity, it reflects back that smile, and before its tongue can lisp a single articulate sound, mind communes with mind in the silent but expressive language of the spirit. Perhaps none but a mother can tell the deep-felt joy which the first "answering look" of love from her infant carries to her heart. Where were all this without the "precious eyesight?" No joy more peaceful, holier, or unselfish, finds access to the soul.

How soon is the recognition of the mother followed by other definite impressions, conveyed

to the mind through "childhood's eager gaze;" others around are known—the toy, the domestic animal, the picture recognised as such; at last the printed page, the grand fount of knowledge opened, with all its blessings. Then comes, early and strong to some, later and fainter to others, the appreciation of the beautiful, giving pleasure at the time—pleasure to be long looked back upon in after life. How often, when perhaps half the globe asunder, do the thoughts revert to the native home—to the never-forgotten features of the landscape of the birthplace—the hill, the loch,

> "The household tree, through which the eye
> First looked in love to the summer sky.;"

or, still more beautiful than the face of nature, still more fondly remembered, "the old familiar faces." How much is stored up in the mind, transmitted through the "windows of the soul!" Delight at the time, happiness for the future. It was said in a former page, "did not He who made the light make also the eye?" May we not ask, Did not He who formed the material human eye form also that "little world made cunningly," the human being—the immortal spirit of man, enclosed indeed in a "beautiful shell," but made capable of fitting himself, through the

medium of his senses—and by none more than that of vision—for his life, when that beautiful but material shell shall be no more.

Thus of civilized man—what of his untutored brother of the wild? We behold him at the lowest, level with the animal, his vision as theirs — simply sensual perception. A little higher in the degrees of humanity, aided by his human hand, we find him constructing habitations, clothing, weapons, it may be, rudely ornamented; rarely, as in the North American Indian, while yet unpractised in the arts of civilization, do we find him rising to some appreciation of the beautiful. It were long to trace, with the education of human nature, the education of the eye; how, rising through every gradation, from being satisfied with the distorted, monstrous figures, the bright and gaudy colouring or rude drawing of primitive nations, it learns critically to measure the proportions of the statues of Greece or Rome, or to dwell with pleasurable appreciation upon the subdued tone and delusive foreshortening of the masters of painting. Can we trace this educability of the eye to any peculiar endowment of its bodily components—to any portion of its curiously wrought structure? Surely not; surely

it must belong to those inward powers, that "inward sight," so mysteriously linked in function and application with its material correspondent.

Perhaps in nothing does the capability of the immortal spirit of man shine more conspicuously forth than in those cases in which deprivation of one or more of the senses shuts out knowledge, not from one entrance only, and throws the mind back upon itself. Of these, at once the most illustrative and best known is that of the American Laura Bridgman, who at two years of age was "deaf, dumb, blind, and possessed only a slight consciousness of smell or taste," every avenue, but that of feeling, through which the imprisoned soul might communicate with the external world closed. "The darkness and the silence of the tomb were around her;" "brothers and sisters were but forms of matter which resisted her touch, but which differed not from the furniture of the house, save in warmth and the power of locomotion." "But the immortal spirit which had been implanted within her could not die, nor be maimed nor mutilated." Strange as it may appear, this interesting female has been taught—taught to read the

raised letter, to write and express herself intelligibly, to converse by means of the deaf-mute finger signs, has been made a happy, intelligent human being; and thus, although —as Mr. Charles Dickens has described her— "built up, as it were, in a marble cell, impervious to any ray of light or particle of sound," the soul within has eagerly seized upon the one beam of light streaming through the one little chink—the sense of touch—submitted it to the transparent, but analytical agency of its own powers, and like the prismatic spectrum, spread it out in the dark chamber within, in the varied hues of knowledge and bright colours of a happy mind. How forcibly does this illustrate what is within man—the unquenchable spark of immortality—the human mind — "that internal vision" illumed by "celestial light," which

> "Shines inwards, and the mind through all her powers
> Irradiates; there plants eyes."

But the converse may be the case; the eye itself may be perfect, and yet the mind of idiotcy make no response: the animal wants are sought as by the animal—beyond, all is darkness. Even here benevolence and philanthropy have stepped in, to show that through

this sense is a means of rousing the latent spark of intelligence, though it burn but feebly, and the Christian labours of Guggenbuhl and others have proved that, along with other means, powerful and unusual impressions exerted upon the sense of sight in idiotcy are capable of arousing such amount of intelligent attention, as may afford the groundwork of future progress.

It is interesting to inquire from which of the two senses, sight or hearing, man's mental development and progress receives the greater amount of assistance; much, probably, depends upon his relative position in the world. Among savage or uncivilized tribes, as among the lower animals, loss of sight must, almost more than any other physical disability, subject the unfortunate to probable loss of life—perhaps mercifully. Its importance to mere existence is paramount—to mental enjoyment, as far as such a term is admissible, its contribution must depend upon the mental peculiarity of the individual possessor.

In civilized communities, perhaps greater satisfaction of mind and more abundant sources of enjoyment are within the power of the blind than of the deaf; the comparison is, however,

difficult, and open to great difference of opinion. Much depends upon the constitution of the individual mind deprived of the one sense, and upon the peculiar facilities for acquiring knowledge, and capability of entering into the pursuits and the amusements of those around. The latter capability, fortunately for themselves, the blind appear frequently to possess largely, sometimes in a measure almost to make them forget their privation. A blind gardener has been known to enter with all enthusiasm into the discussion of the colours and forms of his favourites; and all have heard, at least, of the blind traveller, Holman, whose life has been spent in visiting foreign countries and celebrated scenes. If the ears of the blind are open to all harmonious sounds, to heaven-descended music, to the magic of the human voice, they have no sense for the harmonies of vision—the glorious sun, the landscape, the looks and smiles of those they love are unknown. Nor is the loss unfelt—the blind seem often to have strong and painful cravings, more especially for the latter happiness, which sight alone can bestow. The merciful provision which renders other senses more acute when one is lost, may enable the blind to trace accurately every form and fea-

ture; but the play of those features, the glance or look of the eye, no touch can tell them of.

We cannot possibly enter into the ideas which the blind from birth form respecting external objects, more especially colours, and it is not improbable that their conceptions are regulated by the impressions conveyed through the other senses. To us, the mental conception from which the blind man expressed his idea of the colour scarlet, as of the "sound of a trumpet," appears purely arbitrary; but yet there may be some thread untraced, some connection of analogy we dream not of, betwixt the impressions of the senses. This comparison of idea, of course, is totally different from that partial substitution, so to speak, that extreme susceptibility which the remaining perfect senses acquire when either sight or hearing is closed. The quickness of ear and delicate sense of touch in the blind are proverbial. A popular periodical* has lately given an interesting account of a blind sculptor, a native of the Tyrol, who, by his sense of touch alone, is able to produce even accurate likenesses in bust, acquiring a knowledge of the features to be copied by simply passing his fingers over them.

* *Chambers's Journal*, October, 1850.

Although every year of the world's age sees new contrivances, adapted by philanthropy to mitigate the loss, and to increase the comfort of the blind, every year renders man's eyesight more precious to him; never were the "ample" pages of the book of knowledge more widely spread, never richer with "the spoils" of ancient time, with the triumphant results of our modern era. From the press there flows ever, night and day, an unceasing stream of knowledge. Surely, it needs not here to point to the great and abundant blessing which every man in this realm, from the peer to the peasant, may, unfettered by the censor or the priest, draw from the printed page, that common treasury in which are laid up the best thoughts of the best men. If the sound of their voices has long ceased upon earth—if our senses cannot hear their words, our eyes can read the silent language of their spirits.

But not the printed page of man's works is it which alone yields knowledge; his manifold inventions, his splendid triumphs of engineering science or of architectural magnificence, his nicely calculated mechanisms, the beautiful textures of his looms, the teeming conveniences of social life, all speak to us words of

instruction through the sense of sight. As well might we try to count the rain-drops which swell the fountain, as to pass in review all those things which God has given to man, through man, which feed the streams of human knowledge and power. What thinking man could walk through the "long-drawn aisles" of the Crystal Palace of 1851, surrounded by the trophies of man's industry, the conceptions of his brain embodied by the labour of his hands, and not feel reason to bless God for all his good gifts "in wisdom, in understanding, and in knowledge, and in all manner of workmanship"—"for He alone filleth the heart with these things"—to bless Him for the bodily eye to see, for the mental eye, the capacity to understand.

Again it is repeated, "the eye to see, the capacity to understand." The mere seeing—the child-like, wondering, undirected gaze of the unthinking or uneducated—can scarce give new or true ideas, or originate those higher thoughts which elevate the mind above the fascinations of sensual indulgence. If the eyes of men are to perform their part in the great upward movement, in the mighty upheaving of human intellect, which is now begun, man must

be taught how to look through these "windows of the soul"—must know how, through the sense of sight, as well as through that of hearing, to supply unto themselves that stimulus which their nature ever craves, which it must have, and will have, and which, unsupplied to it through the higher, will be sought through the medium of the lower senses. On those who feel and know the unnumbered blessings which spring from an enlightened use of those higher senses devolves the duty of guiding their less favoured brethren on the same path, of giving them eye-drink and ear-drink—giving, where they can, cheerful sights and sounds at home, objects of interest and for thought abroad. Thus will they most surely assist in establishing the cause of order and temperance, of social and moral elevation, of enlightened religious feeling, and thought, and action.

It is interesting to remark how much more importance the ancients attached to the mode of imparting knowledge by the sight than we do; the symbolical meaning attached to colours is a fact testified not only in the heathen mythology, but even in the Bible itself. In all probability, in the painting in the ancient Egyptian temples and tombs, in

that of the curious monuments of Etruria, of Copan and Palenque, in Central America, &c., colours were used, not by chance, or to suit some mere external idea of harmonious combination, or pleasing contrast, but for the express purposes of conveying to the mind, especially in religious worship, definite ideas connected therewith.

Nor is it the useful only which man's eye drinks in for the nourishment of his spirit; the beautiful also exists—a means of elevation above things grovelling and sensual, given by God to man. Nor can we doubt what all creation proclaims in its fair face of attractive loveliness: "Behold the lilies of the field," why were they made so fair? Why all the beautiful forms and colours of the flower world? The perfecting of the seed, we know well, needs not the beauty of the flower, and for this we can trace no other object than to delight man's sight, telling of God's love, to

> "Comfort man, to whisper hope
> Whene'er his faith grows dim;
> For whoso careth for the flowers
> Will care much more for Him."

But in vain for its highest ends would the brightest scenes of this world of matter be

represented to the bodily eye, were that inward power ungiven by which man feels the influence not simply of material beauty, but of the presence of God in all that is beautiful in nature. "In the uniform plain bounded only by a distant horizon, where the lowly heather, the cistus, or waving grasses deck the soil; on the ocean shore, where the waves, softly rippling over the beach, leave a track green with the weeds of the sea—everywhere the mind is penetrated by the same sense of the grandeur and vast expanse of nature." "Everywhere, in every region of the globe, in every stage of intellectual culture, the same sources of enjoyment are alike vouchsafed to man. The earnest and solemn thoughts awakened by a communion with nature intuitively arise from a presentment of the order and harmony pervading the whole universe, and from the contrast we draw between the narrow limits of our own existence and the image of infinity revealed on every side, whether we look upwards to the starry vault of heaven, scan the far-stretching plain before us, or seek to trace the dim horizon across the vast expanse of ocean."*

* Humboldt.

We gaze upon the face of nature, and our minds mirror her ever-changing features; whether brightening in the rosy light of morning, or glowing in the meridian beam, they "shed sunshine through the heart," or, shadowed by the dark cloud, infect our spirits with their own gloom. We gaze upon the face of a friend, and feel a stronger influence still; varied expression in every feature tells of the conscious spirit within; but, like the sun, the eye lights up the whole—through it the silent spirit-language passes with double impress—through it reaches our minds, full oft our hearts; all know it, all have felt its power, compelling in its fascination as that of the Ancient Mariner—"teaching beauty," as nothing else can teach it, from the bright eyes of woman, or in the calm, clear look of the loved or revered, imparting "access in every virtue." Full oft may the eye more eloquently reveal what the tongue cannot, would not, speak; tell in its clear depths of innocence and truth, or downcast, shaded from another's gaze, express in natural language the consciousness of guilt, or the acknowledgment of shame.

Scarcely is there hope that to the confirmed sceptic, who blinds himself to the light of

truth, anything which has been said in the foregoing pages will bring conviction; whilst wilful pride obscures the mental vision,

"Not worlds on worlds in phalanx deep"

will speak of God to the darkened mind; but remove the veil which the evil will, or pride of intellect, has drawn down, and the lowliest weed will carry evidence to the understanding which it cannot refuse.

Many there are carelessly indifferent, without formed opinion, possessed of abundant leisure, opportunity, and mental capability, who waste, in frivolity or idleness, time and powers which might open up to them the treasure of God's creation, give them new life, new interests, true satisfaction, give elevation to the mind and thought, too apt to sink into sensual indulgence. Perhaps, to some of this class, the exposition, however imperfect, of one little work of God may awaken desire to know more of the beauty which He has given to the things of matter, which day by day are stared at without thought, or at best with childish wonder, knowing not, nor caring to know, not even the simplest arrangements and building up of the house they live in. Nature is Truth,

because it is of God, and Truth is instructive beauty. Not one particle of her wide domain is without its interest; it matters not which. Take the broader distinctive features of the animal or vegetable world—the field is inexhaustible; investigate with the microscope the minutest atoms of structure, or direct the telescope to worlds and systems far, far removed beyond our power of calculation—all is full of interest without end.

Lastly, let it not be forgot that, however perfect the structures—however exquisite the adaptations of the material organ which it has been the object of the foregoing pages to explain — however beautiful the scenes and things of this beautiful world, the works of God, the works of man—however extensive the knowledge to be acquired, these things are but means to an end—are but the fleeting things of time leading to eternity; that, real as they appear to us here, there are far brighter realities—those of the eternal world, near the throne of God. Let it not be forgot that there are other things than those we can touch with our bodily hands, or see with our bodily eyes, real and true; all cannot, perhaps, see them alike; some cannot see them at all, because they will

not, for they "love darkness rather than light;" still, the truth of God—immutable, unchangeable, eternal as his own nature—*is*, whether man sees it or not; its light ever shines in the believing, loving heart, bringing comfort and peace here, and hope for hereafter; hope, that when the bodily eyes are glazing in death, and "those that look out at the windows" are darkening—when the world, its bright scenes and familiar objects, its hopes, its joys, its sorrows, and—best loved, last looked upon—the faces of the near and dear, are fading fast from the sight, the mental, spiritual eye of faith and of love may open clearer and clearer upon the brighter things of its eternal home, and accustomed to the light of God's truth here, find itself in its real element when, freed from the gross covering of earthly matter, it wakes in that heaven of which God is the true light—the true and only source of truth, of love, of all things.

THE END.

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